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THE GRAPE LEAFHOPPER IN THE LAKE ERIE VALLEY.

By Fred Johnson, *Agent and Expert.*

INTRODUCTION.

For several years past the grape leafhopper, *Typhlocyba comes* Say (fig. 1), has been increasing in destructive numbers throughout the vineyards of the Lake Erie Valley, and since 1910 it has been recognized as a serious menace to the grape-growing interests of that region. During the years 1910 and 1911 vineyard experiments for the control of this pest were conducted by the members of the field laboratory force stationed at North East, Pa., working under the direction of Mr. A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations of the Bureau of Entomology. Owing to the pressure of work involved in the conduct of numerous vineyard experiments against this pest, and also against the rose-chafer (*Macrodactylus subspinosus* Fab.) and the grape-berry moth (*Polychrosis viteana* Clem.), it was impossible to make a detailed study of the life history of the grape leafhopper during those seasons. As most of these field experiments had been brought to a successful termination at the close of the season of 1911, the investigations for the season of 1912 were devoted largely to life-history studies of this pest. In this work, which was carried on at the field laboratory at North East, Pa., the writer was assisted by Mr. E. R. Selkregg in the recording of the data bearing upon the various stages of the life history of the insect.

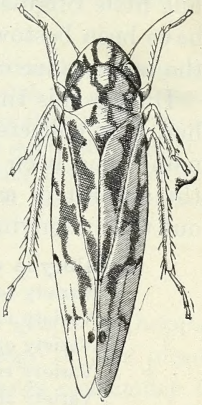


Fig. 1.—The grape leafhopper (*Typhlocyba comes*); Adult, winter form. Greatly enlarged. (Original.)

The following pages contain a record of these life-history studies, together with a short historical account of the part this insect has played as an enemy of the grapevine in other grape-producing sections of the United States and Canada. A detailed account is given

of its habits and destructiveness, the kinds of remedies that have been devised for its control, and the nature of the spray equipment and spray material which, in recent experiments, have proved most effective in holding the pest in check.

HISTORY.[1]

The first published record of this insect was made in 1825, when specimens from Missouri were described under the name *Tettigonia comes* by Thomas Say. It was next mentioned by Fessenden in 1828 as being a serious pest in Massachusetts. In 1841 T. M. Harris, in his Massachusetts report for that year entitled "Insects Injurious to Vegetation," gives a detailed description of the insect and an account of its habits, life history, and injury to the grapevine. These observations of Harris coincide quite closely with those recorded by the more recent workers who have taken up the study of this pest. Since the date of Harris's report the grape leafhopper has become increasingly prominent as a vineyard pest, and in almost all parts of this country and Canada it has, at some time or other, appeared in sufficient numbers to prove a real menace to the grape-growing industry. Although frequent mention of its injurious occurrence in many parts of the country since 1841 is to be found in entomological literature, but little original study, from an economic point of view, seems to have been bestowed upon this insect, for most of the references have the appearance of being taken from Harris's account.

During this time, however, a great variety of forms of this species had been collected, and as a result no less than six different specific names had been given it. In 1898 the subfamily Typhlocybinæ was the subject of a special study by Prof. C. P. Gillette, who worked out the synonymy of the insect as follows:

Typhlocyba comes Say, 1825.
Variety *basilaris* Say, 1825.
Variety *vitis* Harris, 1831.
Variety *affinis* Fitch, 1851.
Variety *vitifex* Fitch, 1856.
Variety *ziczac* Walsh, 1864.
Variety *octonotata* Walsh, 1864.
Variety *coloradensis* Gillette, 1892.
Variety *maculata* Gillette, 1898.
Variety *scutellaris* Gillette, 1898.
Variety *rubra* Gillette, 1898.
Variety *infuscata* Gillette, 1898.

By 1897 it had become so serious a vineyard pest in California as to be placed next in destructive importance to the grape Phylloxera (*Phylloxera vastatrix* Planch.) and was the subject of a detailed

[1] The titles of papers and books, and their places of publication, are not given under this and other headings, but may be found in the Bibliography, pp. 43–47, by looking for the year indicated and, under that, for the author.

study by Prof. C. W. Woodworth. In 1901 Slingerland made a very complete study of the life history of the eastern form, *Typhlocyba comes* Say, and of remedial measures for its control, in the vineyards of Chautauqua County, N. Y., publishing the results in 1904. In 1908 Prof. H. J. Quayle conducted a similarly thorough investigation of the western form in the vineyards of California. Investigations of more recent date have been carried on in Chautauqua County, N. Y., by F. Z. Hartzell, in 1912, and by the Bureau of Entomology, United States Department of Agriculture, at North East, Pa. (See Johnson, 1911 and 1912, in Bibliography.)

ORIGIN AND DISTRIBUTION.

Since *Typhlocyba comes* and its several varieties are of common occurrence on native grapevines in the wild state almost everywhere that the grapevine is found throughout the United States and Canada, and since this species is not recorded as occurring in Europe, it is doubtless a native American species.

It was first recorded from Missouri in 1825, and since that date it has been reported as occurring in destructive numbers in nearly every State in which cultivated grapevines are grown, either in a commercial way or for home use. The following statement by Slingerland in regard to its occurrence is taken from Bulletin 215 of the Cornell Experiment Station, pages 84–85:

> In nearly all discussions of the insect enemies of the grape during the past seventy-five years, the grape leafhopper has been put in the front rank with the most destructive ones. The records show that it has deserved a prominent place in the rogues' gallery of grape pests in Massachusetts since 1828, in New York since 1856, in Illinois since 1871, in Michigan and California since 1875, in Ohio since 1888, and in New Mexico, Colorado, North Carolina and Minnesota since 1890. Destructive local outbreaks have also occurred in other States.

FOOD PLANTS.

During the growing season of the grapevine the grape leafhopper apparently confines its attacks entirely to the foliage of this plant. Early in the spring, however, before the grape leaves commence to unfold, the adult leafhoppers feed on the new foliage of almost any and all plants with which they come in contact, whether it be the foliage of trees and shrubs in woodlands or the weeds and grasses in the more open sod and pasture lands. The following is a list of trees, shrubs, and weeds the foliage of which showed evidence of feeding by the adults in the spring of 1912: Beech, maple, wild cherry, wild apple, hawthorn, dogwood, wild plum, hornbeam, hackberry, honeysuckle, wild grape, Virginia creeper, raspberry, thimbleberry, blackberry, strawberry, goldenrod, nettles, wild columbine, and a great variety of weeds and grasses. Along ravines and woodlands bordering badly infested vineyards, where large numbers of the adults

hibernate, the low-growing foliage of underbrush and shrubs will have nearly all of the green coloring matter extracted by this pest and present a whitened or sometimes brown appearance before the spring migration of the insect takes place. Those adults which winter in the vineyards feed upon the green blades and leaves of grasses, weeds, and the various plants that are grown as cover crops. When the leaves of the cultivated grapevine commence to unfold there is a wholesale migration from the foliage of the wild plants, and even from the foliage of wild grapevines, to that of the cultivated vines, amounting in the course of a week or so, from about May 10 to 25 in the region of the Lake Erie Valley, to a complete desertion of the foliage of all plants other than those of the wild varieties of grape and possibly the Virginia creeper. The percentage of hibernating adults remaining on the wild grapevines is very small compared with the number found there before the spring migration to the vineyards has taken place.

It has been observed that in seasons when the infestation throughout the vineyard area of the Lake Erie Valley has been light, some of the thinner-leaved varieties, such as Delaware and Brighton, are apparently more heavily infested and suffer more from the attacks of this pest than do the thicker-leaved varieties, such as Concord and Niagara. On the other hand, when these insects are very numerous throughout a large vineyard area but little if any difference in respect to the amount of injury to the different varieties can be observed. Usually vines of weak-growing varieties suffer most from attack by this pest, yet it has been observed, in run-down Concord vineyards in which the foliage was sparse, that reproduction of the leafhopper during the summer of 1912 was not so great on such vines, even where the overwintering adults were very numerous in spring, as in adjacent vineyards where vines of the same variety were more vigorous and the foliage was more dense.

Although many observations have been made to determine if this insect reproduces on the foliage of plants other than the wild and the cultivated grape, all the evidence secured has been of a negative nature. Attempts were made to rear nymphs on the foliage of the raspberry, which appears to be a favorite food plant of adults when they leave hibernating quarters in the spring. A large number of adults were confined in Riley cages containing raspberry plants. Although much of the foliage was whitened as a result of their feeding and many of the adults lived until about the middle of July, there was no appearance of nymphs at any time during the season upon the foliage of these plants. All observations during this investigation indicate that this insect reproduces only on the foliage of the wild and cultivated grapes, and that where vines of cultivated varieties are available it shows a preference for them and reproduces more freely upon them than upon the wild species.

CHARACTER OF INJURY AND DESTRUCTIVENESS.

The grape leafhopper injures the grapevine by attacking the foliage. It is a sucking insect in both the nymphal and adult stages and injures the plant by inserting its threadlike proboscis (fig. 2) into the underside of the leaf and extracting the juices therefrom. The result of these punctures, and more especially the removal of the juices, is first evidenced by a yellowing or whitening in patches on the upper surface of the leaf (fig. 3), which later turns brown, and finally the leaf falls from the vine prematurely. Where the injury is severe, the whole leaf dries up and becomes almost functionless long before the normal ripening period of the fruit arrives. This arrested functioning of the foliage as a result of attack by this pest has a tendency, when the injury is severe, to check the development of the entire vine, frequently to such an extent that the cane growth is considerably shortened, the size of the crop of fruit reduced, and the quality rendered inferior by a reduction of its sugar content. During very dry seasons the fruit on heavily infested vines is badly spotted by the droppings of the adult insects.

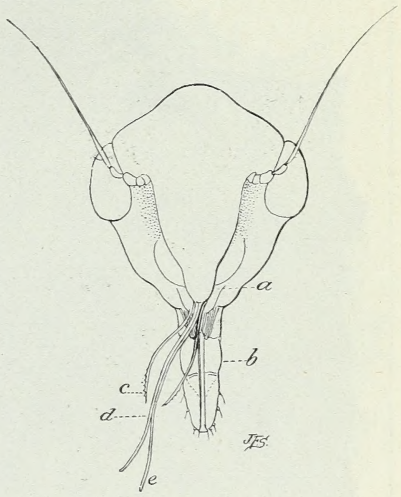


FIG. 2.—Head of grape leafhopper, showing mouthparts: *a*, Labrum; *b*, labium; *c*, mandibles; *d*, maxillæ; *e*, maxillary seta. Greatly enlarged. (Original.)

The overwintering winged adults commence to attack the new leaves of the vines when the shoots are a few inches in length. Usually the sprouts starting from the base of the vine and the new growth along the lower trellis are the first parts to be attacked. When large numbers of the adults are present feeding on this new growth, patches of yellow soon appear on the upper surface of the infested leaves, and in a short time these injured areas dry down and become brown (fig. 4), and the leaves assume a crumpled appearance, the result being a stunting of the badly infested shoots. During this time shoots higher up on the vine, being less heavily infested, have made a stronger growth which, where the vines are vigorous, soon overshadows the stunted, badly infested shoots along the lower trellis. Consequently it frequently happens that this growth on the lower trellis develops few or no long, normal, healthy canes.

This condition is of considerable importance, since it is from the healthy, well-ripened canes springing from the lower trellis that the

fruiting canes for bearing the next season's crop are selected. For the first season or two that a vigorous vineyard is infested, this stunted condition of the bearing canes is overlooked by all but the most observant vineyardists. With each additional season of heavy infestation, however, it becomes increasingly difficult to secure well-placed, robust, bearing canes, and there is a corresponding decline in the quantity and quality of the crop until in some instances the

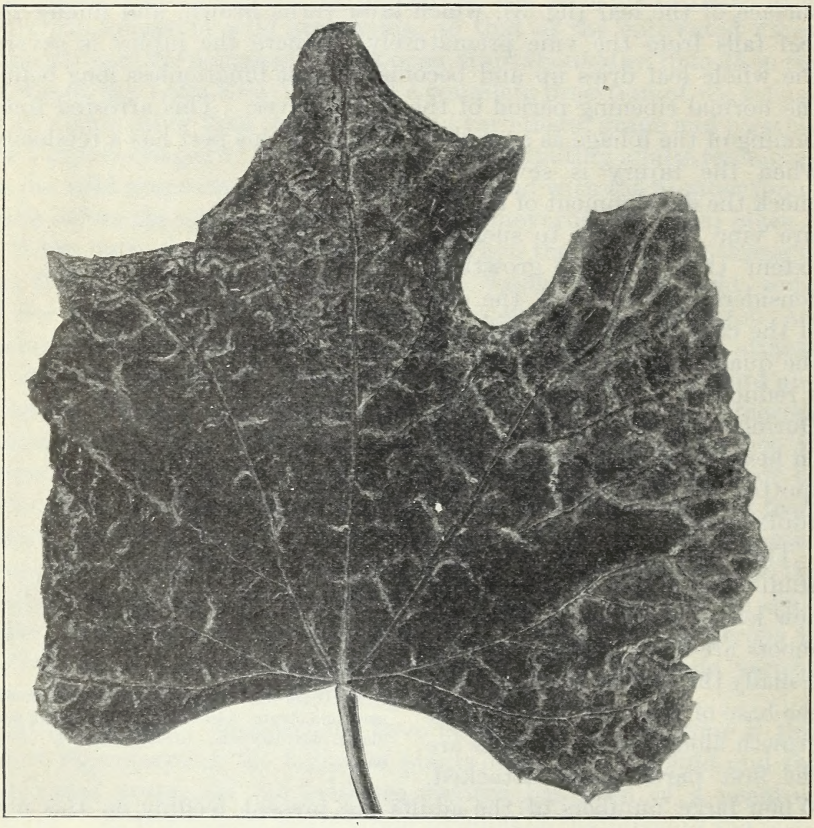


FIG. 3.—Grape leaf showing first evidence of whitened spots resulting from feeding of adult grape leaf-hoppers in early summer. (Original.)

crop yield is so reduced that it pays little more than the season's cost of operating the vineyard.

OCCURRENCE AND DESTRUCTIVE OUTBREAKS.

In speaking of the occurrence of this insect Slingerland has said: "It has its periods of great destructiveness and comparative obscurity, or its 'ups and downs,' like most of our insects." It may exist on vines in limited numbers in some grape-producing section for several seasons without attracting much attention either in regard to its

presence or its injury to the foliage of the vines. During these periods serious injury to the vines or to the crop yield is confined to a few rows of vines adjacent to ravines, woodlots, or rough pasture lands. This limited amount of injury usually attracts little attention and no attempt is made by the vineyardist to hold the insect in check. Then a series of seasons favorable to its development may occur, and there appears to be a steady yearly increase in numbers and further encroachment into the infested vineyards. Finally it becomes so abundant and thoroughly disseminated throughout the vineyard

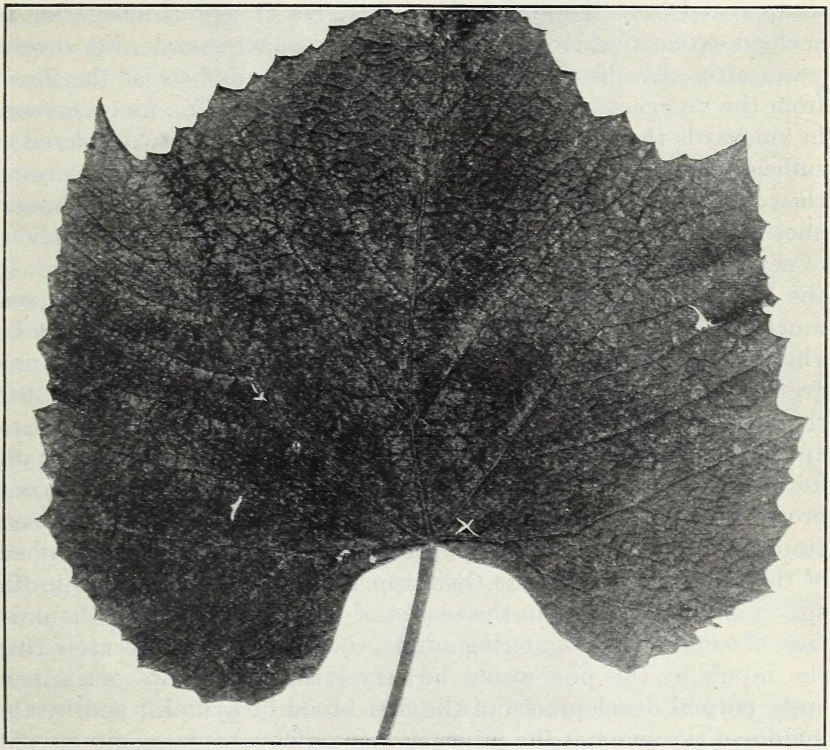


FIG. 4.—Grape leaf in advanced stages of injury. Areas between veins have turned a reddish brown. (Original.)

area, and its destruction is so obvious, that it attracts general attention, and the so-called "outbreak" causes considerable alarm among the vineyardists. Such "outbreaks" have been recorded from many States, as is indicated in the quotation from Slingerland under the caption "Origin and distribution." The same author states that "outbreaks" have occurred at frequent intervals in various parts of the State of New York as follows:

In Wyoming County in 1860; in the Hudson Valley in 1865, 1867, 1882, 1887, and 1897; on Crooked Lake in 1880; in Jefferson County in 1887 and 1888; in central New York in 1895 and 1899; and in Chautauqua County in 1900 to 1904.

During the period from 1897 to 1904 the writer of this paper resided at Westfield, N. Y., during the summer months and had the opportunity to observe the development of the outbreak of 1900 to 1904. There was not a sudden appearance of this pest in a single season, but a steady increase in numbers for several consecutive seasons preceding the so-called outbreak of 1900. On the other hand, during the summer of 1903 there was an apparent sudden disappearance of the insect from many vineyards which during the two previous seasons had been badly infested and suffered serious injury to the foliage during the seasons of 1901 and 1902. In fact, after the season of 1904 this pest disappeared from the vineyards of this area of serious infestation to such an extent that treatment was deemed unnecessary. For several years after this disappearance in destructive numbers of the insect from the vineyards in the vicinity of Westfield, N. Y., its occurrence in vineyards throughout the Lake Erie Valley was not considered of sufficient importance to warrant treatment. In 1909, however, during the conduct of vineyard experiments at North East, Pa., the appearance of this pest in injurious numbers was again observed in portions of several widely separated vineyards throughout the township. In the latter part of the season of 1910 the area of serious injury was much more widespread and its increase was viewed with alarm by vineyardists, and in the season of 1911 a number of the more progressive growers equipped themselves to fight the pest. During 1911 the injury wrought by the pest was greater than in preceding years, and the infestation was more widespread. The summer was unusually hot, and this resulted in the development of an almost full second brood which worked great injury to the vines late in the season. Immense numbers of adults went into hibernation, and large numbers of them emerged and made their appearance in the vineyards in the spring of 1912. Early in the season of 1912, on account of the presence of so many overwintering adults, there was every indication that the injury by this pest would be very great. There was an apparently normal development of the first brood of nymphs, and by the middle of the summer the injury in many vineyards was quite severe. Fortunately, however, the months of July and August were unseasonably cool. The low temperatures which prevailed during these two months so greatly retarded the development of the nymphs of the first brood that only a small percentage of the adults transforming from them deposited eggs for a second brood of nymphs. Hence there was not such a great increase in numbers of the insect during the latter end of the season of 1912 as there was at the end of the hot season of 1911. Nevertheless the injury done by this pest to many vineyards was very great. The injury to the foliage, coupled with the coolness of the summer, resulted in badly infested vineyards, in a retardation of the cane growth, in a lack of proper development of the size of the

berries in the cluster, and in a deficiency in the sugar content of the fruit. For these reasons the aggregate injury by this pest during the season of 1912 was fully as great as in that of 1911.

Thus far mention of the destructiveness of this pest has been confined to the vineyard areas of the Eastern States. For more than 25 years this species, *Typhlocyba comes*, including a western variety, *coloradensis* (fig. 5), has caused an enormous amount of injury to the grapevines in the vineyards of California, where it has been recorded as an injurious grapevine pest since 1875. Prof. H. J. Quayle, in Bulletin 198 of the California Experiment Station, states in regard to its destructiveness that "with the exception of the Phylloxera, the vine hopper is undoubtedly the most destructive insect pest of the vine in the State. It is more uniformly present than any other insect attacking the vine, and each year in some parts of the State it occurs in very great numbers, and in such sections it levies a heavy tax upon the vineyard interests."

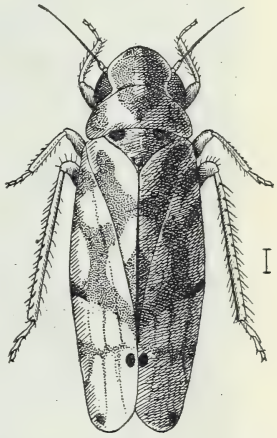


FIG. 5.—A western variety of the grape leafhopper, *Typhlocyba comes* var. coloradensis: Adult. Greatly enlarged. (Author's illustration.)

Thus it is evident that, taken in the aggregate, the injury sustained by the vineyard industry of the East and the West must amount to an enormous sum. It should be remembered, too, that the injury caused by this pest is not confined to the crop of a single season. It frequently happens that a heavy infestation of one or two seasons' duration may so stunt the growth of the vine that its full fruiting capacity may be reduced for several seasons. In fact, if special efforts for the resuscitation of badly injured vines are not undertaken they may never regain their former productive value. Hence the loss to the vineyardist not only consists in the crop shrinkage, but also in the additional cost of the fertilization and care required to get the vine back into full bearing condition.

ALLIED SPECIES.

In the region known as the Chautauqua and Erie grape belt, which includes a narrow strip of territory stretching along the southern shore of Lake Erie from Silver Creek, N. Y., to Harbour Creek, Pa., there are approximately 40,000 acres of vineyard, over 90 per cent of which are of the Concord variety. The species of leafhopper found in injurious numbers in the vineyards throughout this region is *Typhlocyba comes*. Although occasional specimens of other varieties and species may be found, their presence in numbers sufficient to

work a great amount of injury has not been observed. The other species most commonly found associated with *T. comes* is *T. tricincta* Fitch (fig. 6,*b*). This species, when present, is more likely to be found on the foliage of Delaware, Catawba, Brighton, and some of the wild species of grapevine growing along ravines or in woodlands. It is readily distinguished from *comes* by the larger size and by the fact that it has three broad black bars situated as follows: One just back of the head, another about midway across the elytra, and

FIG. 6.—The two species of grape leafhopper most common in vineyards of the Great Lakes Region: *a, Typhlocyba comes; b, Typhlocyba tricincta.* Greatly enlarged. (Original.)

the third at the tips of the elytra. Nymphs of *tricincta* (fig. 7) have two black spots back of the eyes and two on the thorax.

While making trips through the vineyard areas along the shore of Lake Erie as far west as Sandusky, Ohio, it was observed that in the Ohio vineyards east of Cleveland *Typhlocyba tricincta* was present in greater numbers than in the vineyards of Chautauqua County, N. Y., and of Erie County, Pa., although more than 80 per cent were still *Typhlocyba comes*. In the vineyards west of Cleveland *T. tricincta*

was present in greater numbers than in the vineyards east of that city. This condition also existed in the vineyards surrounding Sandusky, Ohio. In vineyards on Kelleys Island, North Bass, South Bass, and Middle Bass Islands both *T. comes* and *T. tricincta* were very abundant and there were also a number of other species and varieties in abundance which were not common in vineyards on the mainland, the most common being *T. vulnerata* Fitch. It should be stated that in the vineyards east of Cleveland, Ohio, the vines are nearly all of the Concord variety, whereas west of that city there is a considerable percentage of Catawba and of Early Ohio, while around Sandusky, Ohio, and upon the islands the percentage of the Concord variety is small, Catawba being the variety most commonly

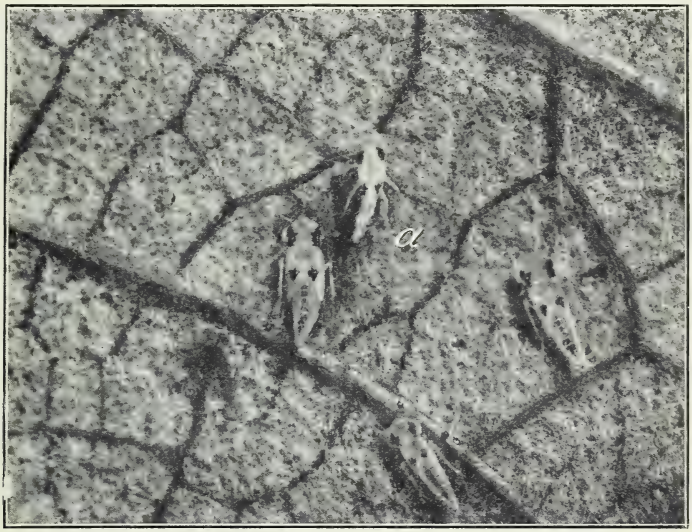


FIG. 7.—Three nymphs of *Typhlocyba tricincta* on underside of grape leaf: *a*, Cast skin of nymph. Enlarged. (Original.)

grown, as also Delaware, Ives Seedling, Elvira, and a number of other varieties used in wine making. In the vineyards on the mainland around Sandusky *T. tricincta* was the species present in destructive numbers. *T. comes* was also present, but only in small numbers.

Observations in the vineyards of Michigan during the seasons of 1911 and 1912 showed that *T. tricincta* is the predominant species in vineyards surrounding Lawton and Paw Paw and in the vicinity of Benton Harbor and St. Joseph. In the vineyards of Michigan *T. comes* is present in even smaller numbers than in the vineyards about Sandusky, Ohio.

Although the development of these two species seems to be almost identical, adults of *T. tricincta* brought from the vicinity of Dover,

Ohio, in the spring of 1912 produced a brood of nymphs which matured to adults. These adults, in turn, produced nymphs which developed to adults of the second summer brood. Observations in the vineyards of Ohio and Michigan, however, during August of 1911 and of 1912 indicate that this species produced a much smaller number of second-brood nymphs than did *T. comes* in the vineyards surrounding North East, Pa.

It should be added that a very large percentage of the grapevines grown in the Michigan vineyards are of the Concord variety, and that on these vines *T. tricincta* is the predominating species, whereas in the vineyards of the Chautauqua and Erie grape belt, where the Concord is the leading variety grown, *T. comes* is the predominant and destructive species.

Little, if any, effort has been made thus far by the vineyardists of Michigan to control *T. tricincta*, although in the season of 1911 it was quite destructive in many vineyards. Several vineyardists in the vicinity of Lawton and Paw Paw were planning to combat it with a tobacco-extract spray in 1912, but although there was a heavy infestation of overwintering adults in the spring these failed to produce a large enough brood of nymphs to injure the vines seriously, thus rendering a spray treatment unnecessary.

DESCRIPTION.

THE ADULT OR WINGED FORM.

The adult grape leafhopper (*Typhlocyba comes* Say) (see fig. 1, p. 1) is an insect about one-eighth of an inch long. The original description of the insect by Say, made in 1825 (see Bibliography), is as follows:

> Pale yellowish with sanguineous spots. Inhabits Missouri.
>
> Body pale yellowish; head, a transverse sanguineous line, profoundly arcuated in the middle, and a smaller transverse spot before; eyes fuscous; thorax with three sanguineous spots, the lateral ones smaller and the intermediate one arcuated; scutel, a sanguineous spot at tip; hemelytra yellowish white spotted with sanguineous; spots arranged two at base, of which the outer one is small and the inner one elongated and abruptly dilated on the inner side at tip; two upon the middle, of which the outer one is elongated in a very oblique line; the two behind the middle, of which the inner one is obliquely elongated, and the outer one smaller and interrupted; and a transverse linear one near the tip, ramose upon the nervures; feet whitish.
>
> Length to the tip of the hemelytra one-ninth of an inch.
>
> The line and spot on the head and the spots of the thorax are sometimes obsolete, but are always visible, and the latter are sometimes connected by curving toward the anterior edge of the thorax. The spots of the hemelytra are also sometimes slightly interrupted, or connected into four oblique bands.

In winter the color markings are deep salmon-red. After the insects have fed upon the foliage of the grapevine for a short time the color becomes paler and is displaced by a light yellow. In the

newly transformed adult these yellow markings are hardly discernible (fig. 8), the whole body being very light straw color. In a short time, however, they become more pronounced. Along toward the middle of August the salmon color begins to appear, first as a light tint on the thorax and at the base of the elytra and in a short time extending to the tips of the wings. As the season advances the salmon color deepens until the insect takes on the more pronounced red markings of the wintering adult.

THE EGG.

The eggs of the grape leafhopper are not more than three-fourths of a millimeter long and are slightly curved (see fig. 10, *d*). They are semitransparent, with a yellowish tinge, and are very difficult to locate, since they are deposited beneath the epidermis of the underside of the grape leaf, which in most varieties is covered with a heavy pubescence. It is very difficult to detect them with the naked eye even after the most careful search. They may be located, however, with the aid of a hand lens or dissecting microscope by examining the underside of the leaf in bright sunlight. Under these conditions the eggs appear as slight shiny elevations under the epidermis. By carefully scraping away the pubescence covering this area the outline of the egg may be more plainly discerned. Figure 9 is an enlarged photograph showing the outlines of two eggs beneath the epidermis of a leaf of Concord grape. The eggs are extremely delicate and are very easily crushed when an attempt is made to remove the thin, semitransparent layer of leaf skin or epidermis underneath which they have been tucked by means of the slender ovipositor of the female (fig. 11). Figure 12 shows the anal segment of a male of the same species, with its genital armature.

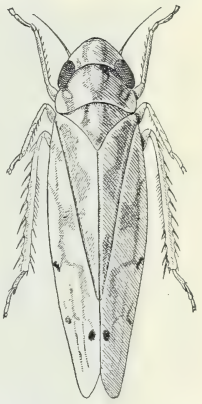


FIG. 8.—Adult grape leafhopper, summer form, showing the lighter shade of color markings of the elytra. Greatly enlarged. (Original.)

The eggs are usually deposited singly over the surface of the leaf, sometimes in or near the ribs and veins, but usually in the spaces between them. They do not appear to be placed in any regular order, but occasionally several may be found in close proximity. In one instance, in the leaf of a Clinton vine, three eggs were found quite close together with the long axis of all extending in the same general direction. Slingerland mentions finding the eggs laid from six to nine in a row in leaves of the Clinton grape. In this variety the leaf is less fleshy and has less pubescence than have the leaves of nearly all of the other varieties of grapes grown in the East. Examinations of the location and proximity of eggs in thin-leaved

species of wild grapevines did not bear out the supposition that deposition in rows is general in the thin-leaved varieties, for in all other cases where eggs were found on them they were deposited with an apparent disregard for regularity of position.

Among vineyardists there is commonly a mistaken idea that the small, transparent globules that are seen on the new growth of the grapevine, especially in the early summer, are the eggs of the grape leafhopper. These are not eggs but are small drops of sap which exude from the rapidly growing leaves and tendrils.

THE NYMPH.

The young grape leafhopper, or nymph, when it hatches from the egg, is very minute, white in color, and of the same general form as

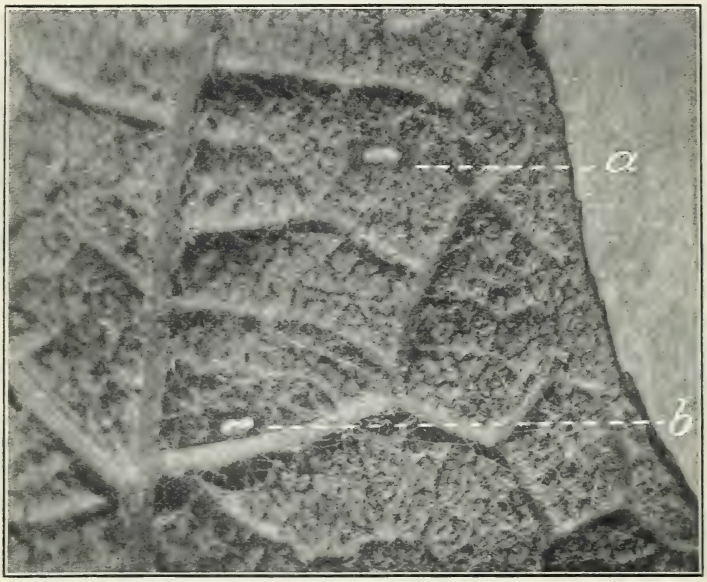


FIG. 9.—Outline of eggs, *a* and *b*, of grape leafhopper on underside of grape leaf with pubescence pushed aside. Greatly enlarged. (Original.)

the adult, but differing from the mature parent in that it does not possess wings. It attains its growth by casting its skin in a series of five molts. These five nymphal stages are represented in Plate I. The time required for the nymph to reach maturity varies greatly with the different individuals. During the season of 1912 rearings were made of a large number of nymphs.

First stage.—The newly hatched nymph has a white body and red eyes. It does not run very rapidly at first, but moves over the underside of the leaf with rather an uncertain, "wobbly" gait. The number of days required for this stage, from hatching to the first

molt, may vary anywhere from 3 to 15. The majority of the nymphs, however, complete the stage in from 3 to 5 days.

Second stage.—In the second nymphal stage the insect becomes more active. The eyes lose some of their red color and the body assumes a yellowish tint, and at the base of the thorax there appear signs of the wing pads in the form of lateral buds. The length of this stage may vary from 1 to 7 days. The majority of nymphs complete the stage in 3 to 4 days.

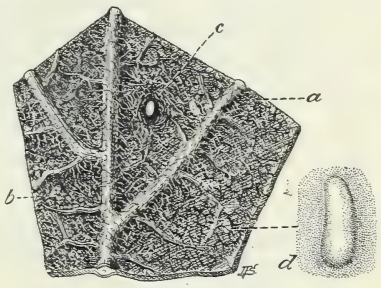


FIG. 10.—The grape leafhopper: *a* and *b*, Eggs, partially shown under pubescence; *c*, egg brought into view; *d*, greatly enlarged egg. All enlarged. (Original.)

Third stage.—The insect in the third stage moves about very actively when disturbed, running with a sidewise motion. Very rarely can one be made to hop for even the shortest distance. The red has disappeared from the eyes, and the yellow markings on the thorax have now become quite pronounced. The wing pads extend to about the caudal margin of the first abdominal segment. This stage may occupy from 1 to 11 days. In most cases from 4 to 6 days is required.

Fourth stage.—In the fourth stage the spines on the segments of the thorax and on the legs are more pronounced, and the wing pads now extend to the caudal margin of the second abdominal segment. This stage may occupy from 3 to 13 days, although the majority of nymphs complete it in 3 to 7 days.

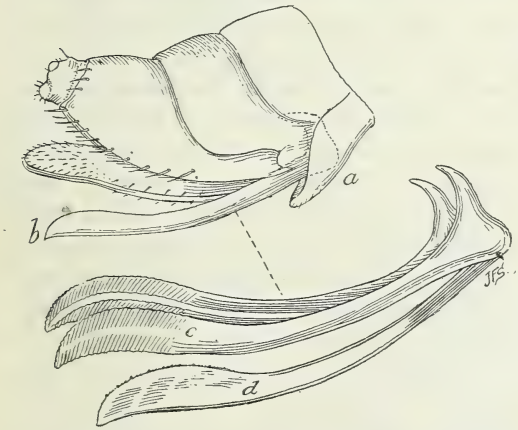


FIG. 11.—Anal segments of female grape leafhopper and details: *a*, Anal segments; *b*, ovipositor in oviposition; *c*, sheaths of ovipositor; *d*, sting. Greatly enlarged. (Original.)

Fifth stage.—In the fifth stage the wing pads are considerably lengthened, extending to about the middle of the fourth abdominal segment. The legs are much longer, and the insect runs very rapidly. This stage may cover from 4 to 20 days. The majority complete it in from 6 to 9 days.

The total length of time required to complete the nymphal stages, from hatching to the last molt, when the mature insect has fully developed wings, may vary from 19 to 37 days.

The number of days required to complete the stages of the nymph were arrived at as a result of rearing 114 nymphs through all of the five nymphal stages from hatching to adult during the season of 1912, and the data given above are based on these rearings. It was observed that variations in temperature greatly influenced the length of the different stages. It was also noted that although there might be a considerable variation in the number of days that were required by nymphs of the same age to complete any one of the stages, the total number of days covered would vary but slightly; since it frequently happened that when one stage was protracted beyond the average period, some other stage would be considerably shortened, and thus the total number of days for the entire nymphal period would be about the same for all nymphs of the same age. (See Table XI.)

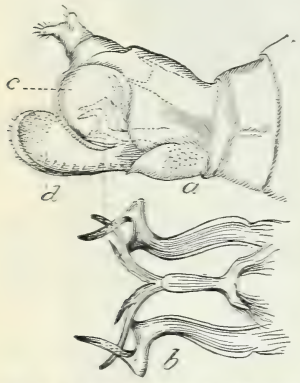
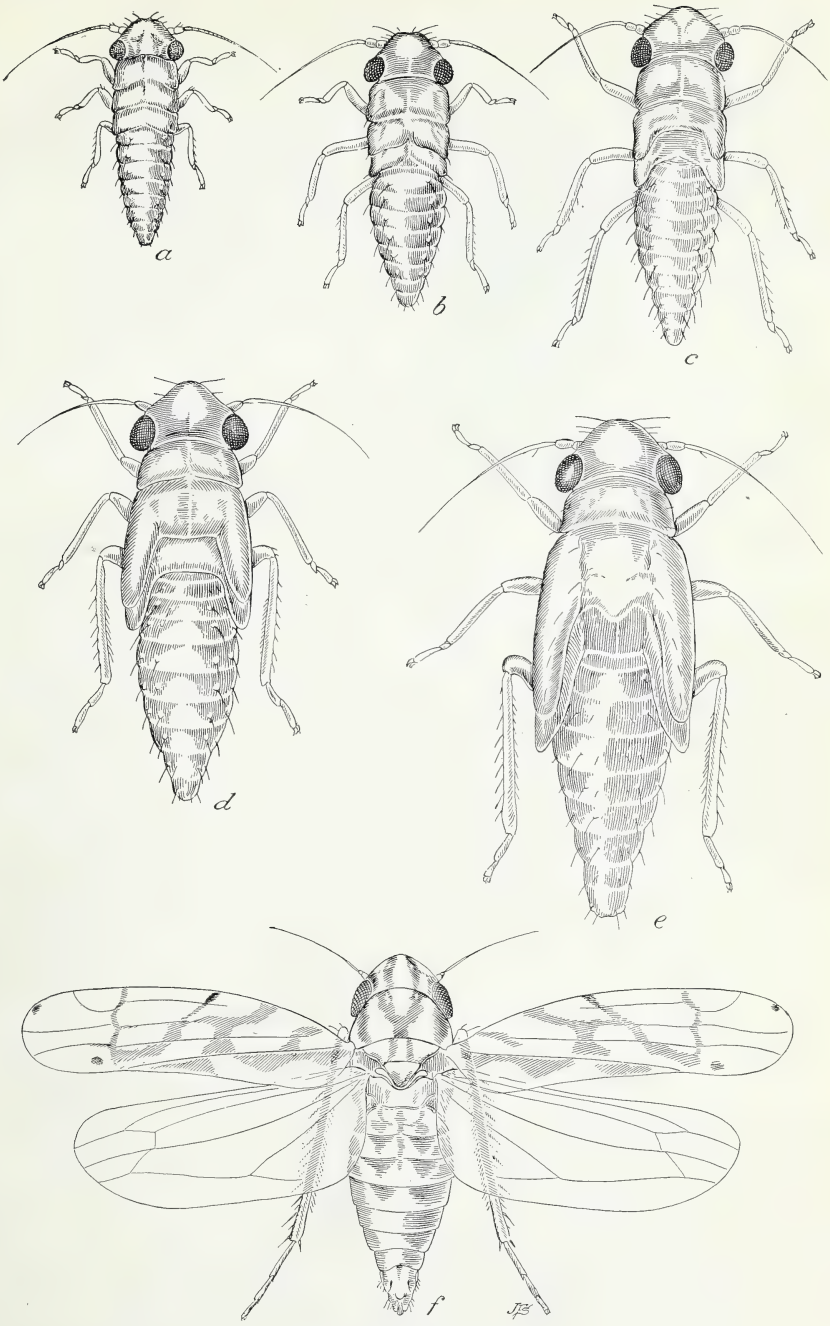


FIG. 12.—Anal segments of male grape leafhopper and details: *a*, Anal segments; *b*, genital hooks; *c*, superior clasper; *d*, inferior clasper. Greatly enlarged. (Original.)

SEASONAL HISTORY.

ACTIVITIES OF ADULTS IN EARLY SPRING.

The adult grape leafhoppers become active in their hibernating places beneath accumulations of leaves, trash, and dried grass during the warm days of late winter and early spring. During the warm sunny hours of such days they rise in swarms about one's feet when tramping through the leaves and dried grass of woodlands and swales which adjoin vineyards which were heavily infested during the preceding season. During these periods of activity they feed on the green parts of almost any plant that happens to be growing near these places of hibernation. At first the green blades of tufts of grass or the leaves of goldenrod or wild strawberry, and a little later the unfolding leaves of wild raspberry and blackberry, appear to form a favorite part of the menu offered by the woodland growth. As the days become warmer the adults extend their flight and feed upon the tender unfolding leaves of nearly all kinds of shrubs and undergrowth. When the new growth of the cultivated grapevine has attained a length of a few inches there is a general migration of the insect to the vineyards. This migration occurs about the middle of May in the vineyards of the Lake Erie Valley, and if the days are warm and bright the desertion of the woodland food plants for the foliage of the cultivated grapevine in the course of a few days is quite complete. In the spring of 1912 this migration from woodlands commenced about May 20. On May 24 the leafhoppers were extremely scarce in woodland places, where until four or five days previous they had been present in swarms since the time of first activity in spring.



THE GRAPE LEAFHOPPER.

The five nymphal stages and adult of the grape leafhopper (*Typhlocyba comes*): *a*, First stage; *b*, second stage; *c*, third stage; *d*, fourth stage; *e*, fifth stage; *f*, adult with wings spread. All greatly enlarged. (Original.)

From this date on, the adults confine their feeding and other activities to the foliage of the cultivated grapevine. About this time the red marking on the elytra disappears and is replaced by a light lemon-yellow. After the adults once settle down on the foliage of the vines in the vineyards there is very little evidence of further migration, and they seldom leave the shelter of the vines except when disturbed, in which case they fly but a short distance and return almost immediately to the underside of the grape foliage. On bright, warm days they become very active on the slightest disturbance of the vine, whereas on cold wet days it is with the greatest difficulty that they are dislodged from the underside of the leaves.

For several days after their appearance on the foliage of the grapevines the adults confine their activities to feeding on the underside of the foliage. This they do by inserting their threadlike mouth parts or proboscis into the tissue from the underside of the leaf and sucking out the juices.

TIME OF MATING.

It is exceedingly rare to find copulating pairs of adult grape leafhoppers before migration to the vineyards takes place. After migration to the vineyards mating is not common until a week or ten days of feeding has elapsed.

The first copulating pair seen during the spring of 1912 was on May 23 upon the foliage of a quince bush in the laboratory garden at North East, Pa. Occasional copulating pairs were seen in vineyards as early as May 25, 26, and 27, but mating did not appear to be general until about June 1. After June 5 mating of overwintering adults was rarely seen in the vineyards, although daily observations were made.

OVIPOSITION OF OVERWINTERING ADULTS.

No direct observation has been made of females in the act of oviposition. A number of experiments were made during the summer of 1912 to secure records of egg deposition and the number of eggs deposited by individual females, but without success. This failure was due to the fact that the leaves of all of the varieties of grapes grown in the Lake Erie Valley possess a heavy pubescence or hairy growth on the underside. This makes it extremely difficult to locate the eggs, since they are inserted within the tissue of the leaf beneath this hairy growth and can only be found after a thorough search. Even then many of them are doubtless overlooked, since it often happens that a large number of nymphs will hatch from grape leaves upon which it has been possible to locate only a small number of eggs after a prolonged and careful search. On June 10 the first eggs seen in 1912 were located on leaves of a Delaware grapevine.

LENGTH OF EGG STAGE.

Since we were unable to secure actual records of egg deposition from which to make a starting point in order to determine accurately the length of the egg stage, an approximation of this period was obtained in the following manner:

During the season of oviposition a number of adults were confined in an air-tight globe cage (Pl. II, fig. 1) upon the uninfested foliage of a small grapevine possessing not more than three or four healthy leaves. After 24 hours all the adults were removed. The vine was protected from further infestation and after seven days had elapsed was examined daily for the appearance of nymphs. A record was made of the date of the first nymphs to appear. These were removed from the cage and all other nymphs to hatch were removed at intervals of 24 hours. In the experiments recorded below the adults were placed on an inclosed grapevine, July 4, at 1 p. m. These adults were removed July 5, at 1 p. m. The newly hatched nymphs were removed on the dates recorded in Table I.

TABLE I.—*Length of incubation period of eggs of the grape leafhopper.*

Date and hour of removal of newly hatched nymphs.	Number of nymphs removed.	Incubation period.
50 adults placed on vine July 4, 1 p. m.; adults removed from vine July 5, 1 p. m.		
1912.		*Days.*
July 17, 1 p. m.	6	11 to 13
July 18, 1 p. m.	46	12 to 14
July 19, 1 p. m.	38	13 to 15
July 20, 1 p. m.	7	14 to 16
July 21, 1 p. m.	5	15 to 17
50 adults placed on vine June 25, 2 p. m.; adults removed from vine June 26, 2 p. m.		
1912.		*Days.*
July 9, 2.30 p. m.	15	11 to 13
July 10, 2.30 p. m.	45	12 to 14
July 11, 2.30 p. m.	13	13 to 15
July 12, 2.30 p. m.	0	.....
July 13, 2.30 p. m.	1	15 to 17
100 adults placed on vine June 27, 2 p. m.; adults removed from vine June 28, 2 p. m.		
1912.		*Days.*
July 12, 2 p. m.	14	13 to 15
July 13, 2 p. m.	44	14 to 16
July 14, 2 p. m.	19	15 to 17
July 15, 2 p. m.	8	16 to 18
July 16, 2 p. m.	1	17 to 19
50 adults placed on vine July 27, 2 p. m.; adults removed from vine July 28, 2 p. m.		
1912.		*Days.*
Aug. 20, 2 p. m.	15	22 to 24
Aug. 21, 2 p. m.	4	23 to 25
Aug. 22, 2 p. m.	11	24 to 26
50 adults placed on vine August 10, 2 p. m.; adults removed from vine August 11, 2 p. m.		
1912.		*Days.*
Aug. 24, 2 p. m.	2	12 to 14
Aug. 25, 2 p. m.	1	13 to 15
Aug. 26, 2 p. m.	3	14 to 16
Aug. 27, 2 p. m.	0	.....
Aug. 28, 2 p. m.	0	.....
Aug. 29, 2 p. m.	2	17 to 19
Sept. 1, 2 p. m.	1	20 to 22

NUMBER OF EGGS DEPOSITED BY AN OVERWINTERING FEMALE GRAPE LEAFHOPPER.

On account of the great difficulty encountered in locating the eggs of the grape leafhopper, a record of the reproductive capacity of the females was secured by confining pairs of overwintering adults upon small grapevines in an arc-light globe cage similar to that shown in Plate II, figure 1, which had been protected from previous infestation, the object being to determine the number of nymphs that appeared on the vines. The pairs used for this purpose were among the first to be found copulating and at a period before any oviposition had taken place. Each pair of adults was allowed to remain on the vine until they died. To avoid the probability of the escape of the adults, only a few examinations were made until the nymphs were nearing the last molt. The parent adults were then removed and a careful count was made of the nymphs found upon the foliage; then the parent adults were returned to the cage until later examinations were made, and this process was continued until the death of the parent adults occurred. After the death of the adults a period equal to the length of incubation of the eggs was allowed to elapse before the final count for the last nymphs to appear was made. Four separate experiments were started May 27 with copulating pairs of adults. Removal of nymphs took place as shown in Table II.

TABLE II.—*Number of nymphs produced by a female grape leafhopper in confinement.*

1912.	CAGE NO. I.	Nymphs removed.
July 11		34
July 17		33
July 25		36
	Total	103
	CAGE NO. II.	
July 11		49
July 17		49
July 25		33
Aug. 1		8
	Total	139
	CAGE NO. III.	
July 10		[1] 4
July 11		56
July 17		34
July 25		18
Aug. 1		1
	Total	113
	CAGE NO. IV.	
July 11		34
July 17		33
July 25		36
Aug. 1		9
Aug. 2		2
	Total	114

[1] Four newly molted adults.

Several additional experiments were conducted in the same manner to determine the number of eggs per female. In each case several copulating pairs of leafhoppers were placed in each cage.

TABLE III.—*Experiment to determine extent of reproduction from four pairs of copulating grape leafhoppers placed in a cage with a small grapevine June 19, 1912.*

1912.	Nymphs removed.
July 27	154
July 30	159
Aug. 22	8
Aug. 27	30
Aug. 29	159
Total	510
Average	127.5

TABLE IV.—*Experiment to determine extent of reproduction from nine pairs of copulating grape leafhoppers placed in a cage with a small grapevine June 18, 1912.*

1912.	Nymphs removed.
July 24	230
July 31	423
Aug. 12	172
Aug. 22	131
Aug. 29	65
Sept. 4	14
Total	1,035
Average	115

TABLE V.—*Experiment to determine extent of reproduction from four pairs of copulating grape leafhoppers placed in a cage with a small grapevine June 19, 1912.*

1912.	Nymphs removed.
July 24	185
Aug. 9	153
Aug. 23	58
Sept. 6	52
Total	448
Average	112

These experiments show that for 20 females the number of nymphs found ranged from 112 to 139 per female. This method of determining the egg-laying capacity of the females did not, of course, take into consideration the number of eggs that failed to hatch, or the number of fatalities which may have occurred among the nymphs after the hatching period, but the fact that the average number of nymphs reared from each of 15 females varied only from 112 to 115 would indicate that under favorable conditions a female may deposit over a hundred eggs, while the 139 nymphs obtained in cage 2 would indicate that under the most favorable conditions some females may deposit about 140 eggs.

FIG. 1.—CAGES USED FOR REARING THE GRAPE LEAFHOPPER, AT LABORATORY, NORTH EAST, PA., 1912. (ORIGINAL.)

FIG. 2.—STEAM-ENGINE POWER SPRAYER USED IN SPRAYING AGAINST THE GRAPE LEAFHOPPER, NORTH EAST, PA., 1912. (ORIGINAL.)

HATCHING OF FIRST-BROOD NYMPHS.

After the finding of eggs in the tissue of the leaves on June 10, daily examinations of infested grape foliage were made both in badly infested vineyards and on vines at the laboratory. On June 18 three nymphs were found on the badly infested foliage of a Delaware grapevine. These nymphs were probably about a day or two old, since they were slightly larger than newly hatched nymphs. They had taken on a yellowish color, which indicated that some time had been spent in feeding, for the newly hatched nymphs before having taken any food are white.

On June 20 a number of newly hatched nymphs were found on Concord vines. After June 20 the hatching of the nymphs became general. By June 26 large numbers of them could be found in all badly infested vineyards in the vicinity of North East, Pa.

The process of hatching was observed in several instances and occupies a period varying from 10 to 25 minutes.

The hatching nymph appears as a small white object projecting through the pubescence on the underside of the leaf. At first its movement is almost imperceptible. Then, after three or four minutes, there is a swaying circular movement of the free end of this white object, each succeeding movement becoming more vigorous. After four or five minutes of this rapid motion the object commences to assume a definite form. The ends of the antennæ are freed, the eyes become prominent, and the stricture dividing the thorax from the abdomen may be distinguished. In a few minutes more the proboscis and the legs may be seen moving, then the circulation of the body fluids becomes visible through the transparent skin, and finally the feet clutch the hairy pubescence of the leaf and the tiny insect draws its abdomen free of the eggshell. By this time the body has dried, and the nymph runs with a rather unsteady gait over the underside of the leaf. Usually, however, its first excursion is a very short one, for it soon settles down, inserts its minute proboscis into the leaf tissue, and makes its first meal on the juices of its host plant.

APPEARANCE OF FIRST-BROOD ADULTS.

During the season of 1912 the first evidence of the appearance of a new brood of adults occurred on July 12, when examinations of nymphs in vineyards about North East, Pa., showed that at this date an occasional nymph was making the last nymphal molt and developing wings. However, winged adults of this new brood were not common in vineyards until from July 16 to 20, and even at the latter date they did not represent more than 25 per cent of the total number of the new brood upon the foliage. In order to secure some of these earliest transforming adults for the purpose of rearing a second summer brood, about 150 of the oldest nymphs that could be found

were placed on the foliage of a young Concord grapevine on July 12. On July 13 several of these nymphs had transformed to adults. On July 16 about 75 per cent of them had developed wings.

MATING OF FIRST-BROOD ADULTS.

On July 22 numerous pairs of adults of the new brood were found copulating on the underside of grape leaves in the vineyards surrounding North East, Pa. From July 23 to 27 copulating pairs of new-brood adults were common, both in the vineyards and in cages at the laboratory. After the latter date only occasional mating pairs of adults were observed, either in the rearing cages at the laboratory or in the open vineyards, although observations along this line were continued during the remainder of the active season.

NUMBER OF EGGS DEPOSITED BY A FEMALE OF THE FIRST BROOD.

On July 26 three copulating pairs of the new-brood adults were placed in separate cages on a Concord grapevine inclosed in an arc-light globe cage similar to those in which pairs of overwintering adults had been confined, the object being to ascertain the number of nymphs that could be reared from them in order to see how it compared with the number produced by overwintering females. The number of nymphs reared from these first-brood females is shown in Table VI.

TABLE VI.—*Number of nymphs produced by a female leafhopper of the first brood.*

Date examined (1912).	Nymphs removed.
CAGE NO. I.	
Sept. 4	12
Sept. 7	5
Sept. 11	7
Sept. 14	9
Total	33
CAGE NO. II.	
Sept. 3	24
Sept. 5	16
Sept. 9	17
Sept. 11	9
Sept. 15	13
Total	79
CAGE NO. III.	
Sept. 4	37
Sept. 7	35
Sept. 11	9
Total	81

In the case of these three females of the first brood, the average number of nymphs produced by a single female was only a little more than half the number produced by the overwintering females under similar conditions.

TERMINATION OF OVIPOSITION OF ADULTS OF THE FIRST BROOD.

First-brood adults placed in cages with grapevines after August 10 gave no evidence of further reproduction, for nymphs failed to appear on the foliage. About 50 adults were placed in each of five separate cages on August 12, 15, 20, and 27, and September 9. No nymphs appeared in any of these cages, indicating that the season of egg deposition for them, at least, had closed.

Since there is a long period over which the nymphs of this first brood transform to adults, an endeavor was made to determine the date at which these later transforming adults would fail to reproduce during the same season. With this end in view, on July 24, 1912, 100 nymphs of each of the five nymphal stages were placed in five separate cages on the foliage of a small Concord grapevine in order to ascertain if the adults transforming from any or from all of the nymphs in these five cages would copulate and produce another brood of nymphs. Frequent examinations were made of all of these cages during the remainder of the season. All of the nymphs in the five cages transformed to adults, but no mating of the adults was observed nor did any nymphs of a new brood appear upon the foliage of the vines in the cages.

On the other hand, in another cage in which 50 adults were placed on July 22, to determine to what extent and how late in the season they continued to reproduce, nymphs continued to hatch as late as September 15. Below is given the daily hatching record of nymphs from these 50 adults:

TABLE VII.—*Hatching record of nymphs from 50 adult grape leafhoppers placed in confinement July 22, 1912.*

Date.	Number of nymphs removed.	Date.	Number of nymphs removed.	Date.	Number of nymphs removed.	Date.	Number of nymphs removed.
1912.		1912.		1912.		1912.	
Aug. 12	38	Aug. 22	143	Aug. 31	52	Sept. 9	25
Aug. 13	132	Aug. 23	76	Sept. 1	96	Sept. 10	13
Aug. 14	172	Aug. 24	83	Sept. 2	108	Sept. 11	8
Aug. 15	245	Aug. 25	50	Sept. 3	115	Sept. 12	6
Aug. 16	173	Aug. 26	137	Sept. 4	95	Sept. 13	4
Aug. 17	139	Aug. 27	108	Sept. 5	89	Sept. 14	2
Aug. 19	272	Aug. 28	5	Sept. 6	48	Sept. 15	6
Aug. 20	250	Aug. 29	73	Sept. 7	49		
Aug. 21	131	Aug. 30	47	Sept. 8	24		

LONGEVITY OF OVERWINTERING ADULTS.

An effort was made to determine the length of life of overwintering adults. Owing to the great activity of the adult leafhoppers it was found to be exceedingly difficult to keep a record of each individual. In order to secure some data on this point 100 overwintering adults were placed on a small Concord vine inclosed in an arc-light globe cage on May 31. A black cloth was stretched over the surface of

the ground so that the dead adults falling from the foliage of the vine might be more easily seen. An examination for dead adults was made every few days by looking for them upon the black cloth. No dead adults were observed to July 12. On July 12 the adults were transferred to a new cage to avoid confusing them with newly transforming adults. During this operation 18 adults either escaped or were killed. In this new cage 82 adults were placed. Dead adults were found in the cage on the dates shown in Table VIII.

TABLE VIII.—*Longevity of overwintering adults of the grape leafhopper.*

Date of examination.	Number dead.	Date of examination.	Number dead.
1912.		1912.	
July 17	1	Aug. 12	3
July 28	3	Aug. 17	2
Aug. 2	2	Aug. 23	4
Aug. 3	[1] 5	Aug. 27	3
Aug. 5	[2] 2	Aug. 30	5
Aug. 7	[3] 3		

[1] Escaped. [2] Killed. [3] Killed by spider.

On August 30 these adults were again transferred to a new cage to avoid their being confused with newly transforming adults. During this transfer 10 adults were either killed or escaped. In the new cage there were 39 adults. The number of dead adults found in this cage is given in Table IX.

TABLE IX.—*Longevity of overwintering adults of the grape leafhopper.*

Date of examination.	Number dead.	Date of examination.	Number dead.
1912.		1912.	
Sept. 4	4	Sept. 20	3
Sept. 7	3	Sept. 26	7
Sept. 12	1	Oct. 2	6
Sept. 14	6		

The last examination was made on October 2, when there were four adults still living. Hence it is evident that some of the overwintering adults may remain on the vines during the entire growing season. Yet in vineyards that were the object of frequent visits during the seasons of 1911 and 1912 it was observed that there was a period, about the middle of the summer each season, when a decrease in the number of hibernating adults was quite noticeable. During the season of 1911 this period of apparent decrease of overwintering adults was about June 25. In 1912 it was about July 15. In both instances this decrease in number of adults occurred about two weeks before the transformation of the new brood in large numbers to adults.

EXPERIMENTS TO REAR A THIRD BROOD OF NYMPHS.

Rearing experiments were also conducted to determine if the adults which transformed from the earliest hatching nymphs of the season would produce a second summer brood of nymphs and also if the adults transforming from these second-brood nymphs would mate and produce a third brood of nymphs.

On July 2, 100 newly hatched nymphs, the product of overwintering adults, were placed on the foliage of a Delaware grapevine inclosed in an arc-light globe cage. By July 28 a few of these nymphs had transformed to adults. By August 14 all of these first-brood nymphs had transformed to adults. On August 26 several nymphs of the second summer brood in the first two nymphal stages were found upon the foliage of the vine. On August 29 all of the adults of the first brood were removed from this cage in order that there might be no confusion with adults transforming from the second-brood nymphs. On September 12 newly transformed adults of the second brood were found in this cage. On September 27 nearly all the nymphs had transformed to adults. The few remaining nymphs were in the last nymphal stage. By October 7 all nymphs had transformed to adults. Frequent observations were made after the appearance of the second brood of adults in this cage, but no mating was observed nor did any new nymphs appear on the foliage of the vine. Hence it would appear that reproduction did not occur among the adults of the second brood during the season of 1912. A similar rearing experiment was made on July 3 by taking 75 of the earliest nymphs to hatch and placing them on a grapevine inclosed in an arc-light globe cage. By July 16 nearly all of the nymphs had transformed to first-brood adults. On August 15 new nymphs of the second brood were present. On August 28 all first-brood adults were removed from the cage. All of the nymphs transformed to second-brood adults. Although frequent examinations were made of this cage for the remainder of the season, there was no evidence of reproduction by these adults of the second brood.

In another rearing experiment the date of transformation of adults of the second brood was secured. The rearings were made by taking nymphs of the first brood that were among the earliest of the season to hatch. They were nearing the last molt when they were placed on a Concord vine in a Riley cage on July 13. By July 16 nearly all of these nymphs had transformed to adults. On July 26 several pairs were observed mating. On August 17 a few nymphs of the second brood in the first and second stages were observed on the grape foliage. On August 28 all adults of the first brood were removed from this cage to avoid confusion with newly transforming adults of the second brood. A record of the dates of transformation of adults of the second brood is given in Table X.

TABLE X.—*Transformation to adults of second-brood grape leafhoppers.*

Date of examination.	Number of adults transformed.	Date of examination.	Number of adults transformed.
1912.		1912.	
Sept. 7	1	Sept. 14	85
Sept. 8	4	Sept. 15	63
Sept. 9	0	Sept. 17	16
Sept. 10	37	Sept. 19	26
Sept. 11	76	Sept. 20	5
Sept. 12	51	Sept. 21	11
Sept. 13	51	Sept. 24	3

The last of the nymphs transformed to adults on September 24. This rearing experiment indicates that the transformation of the second-brood adults which were the progeny of the earliest nymphs of the season to appear upon the vines was much too late in the season for the production of a third brood of nymphs.

REARING EXPERIMENTS TO DETERMINE LENGTH OF NYMPHAL STAGES.

A series of rearing experiments was made to determine the length of the nymphal stages. The newly hatched nymph was placed in a cage made as follows: A hole about an inch in diameter was punched out of the center of a piece of velvet about 2 inches square. The velvet was then placed, nap side against the leaf, on the underside of an uninfested leaf. A square of heavy manila paper of the same size was placed on the upper side of the leaf directly above the square of velvet, to hold the leaf rigid. The newly hatched nymph was then placed on the underside of the leaf in the circular space cut out of the square of velvet. A small watch glass, convex side up, was placed over the circular hole in the velvet so as to overlap about one-fourth of an inch onto the velvet. Then the watch glass, the velvet, the portion of grape leaf, and the square paper were all held tightly together by means of four paper clips, by slipping on one of the clips from each side of the square, making them clasp the paper and the velvet and overlap on to the watch glass and hold the latter firmly in place so that the nymph could not escape. In some instances squares of thin sheets of celluloid were used in place of the watch glasses, but it was found that the small nymphs would sometimes drown in the moisture collecting on the inside of the celluloid. Then, too, the concave of the watch glass made the space larger. Even with the watch glasses, drowning of the nymphs was likely to occur. In order to prevent this, two squares of velvet were glued together with the nap side out. This raised the watch glass a greater distance from the leaf, giving more space between the back of the nymph and the glass, and less drowning of nymphs resulted. Each cage was examined daily; thus the condition of the nymph was observed and

record made of the date of each molt. During this operation the moisture was wiped from the inside of the watch glass.

The period covered by these rearing experiments was from June 22 to October 13. During this time 348 newly hatched nymphs were placed on grape leaves confined in cages similar to those just described. Many of the nymphs either died or escaped before they completed all of the nymphal stages. Nevertheless, complete records of the length of the five stages were secured for 114 nymphs. The greater number of fatalities occurred among the young nymphs during the early part of the rearing season before the leaf cage most suitable for the purpose was secured. After the double thickness of velvet was adopted fewer fatalities occurred.

The lengths of the several stages for the different individuals show a great variation, but it will be noted by an examination of Table XI that the variation of the total length of the five stages for a number of nymphs hatching on the same date is not very great. Changes in temperature appear to be the important factor in determining the length of time required to complete the entire nymphal period.

In the last column of Table XI the average daily temperature for the entire nymphal period of each of the 114 nymphs is given. These average temperatures are computed from the average daily temperatures given in Table XII. The average daily temperatures given in Table XII are derived from daily readings of a maximum and minimum thermometer, located in the garden of the laboratory at North East, Pa., only a few yards distant from the grapevines bearing the individual cages in which the nymphs were reared.

TABLE XI.—*Length of each of the five nymphal stages of the grape leafhopper for 114 nymphs recorded from June 22 to October 13, 1912.*

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average daily temperature for entire nymphal period.
1912.	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	*Dys.*	°*F.*
June 22	June 28	6	June 30	2	July 4	4	July 7	3	July 11	4	19	74.90
July 5	July 9	4	July 10	1	July 13	3	July 16	3	July 25	9	20	76.60
July 9	July 12	3	July 15	3	July 20	5	July 25	5	Aug. 8	14	30	69.97
Do...	July 15	6	July 18	3	...do.....	2	...do.....	5	Aug. 7	13	29	70.10
Do...	...do.....	6	July 17	2	July 21	4	July 28	7	Aug. 8	11	30	69.97
Do...	July 12	3	July 15	3	July 20	5	Aug. 2	13	Aug. 12	10	34	70.04
Do...	July 13	4	July 16	3	July 21	5	July 27	6	Aug. 9	13	31	70.03
Do...	...do.....	4	July 17	4	July 19	2	July 25	6	Aug. 7	13	29	70.01
Do...	...do.....	4	...do.....	4	July 21	4	July 28	7	Aug. 10	13	32	70.11
Do...	...do.....	4	...do.....	4	July 19	2	...do.....	9	Aug. 9	12	31	70.03
Do...	...do.....	4	...do.....	4	...do.....	2	...do.....	9	...do.....	12	31	70.03
Do...	July 12	3	July 15	3	...do.....	4	July 25	6	Aug. 8	14	30	69.97
Do...	July 13	4	July 17	4	July 21	4	July 27	6	...do.....	12	30	69.97
Do...	July 14	5	July 18	4	July 23	5	July 29	6	Aug. 10	12	32	70.12
Do...	July 13	4	July 16	3	July 21	5	July 28	7	Aug. 9	12	31	70.03

TABLE XI.—*Length of each of the five nymphal stages of the grape leafhopper for 114 nymphs recorded from June 22 to October 13, 1912*—Continued.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average daily temperature for entire nymphal period.
1912.	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	*Dys.*	°*F.*
July 10	July 14	4	July 18	4	July 23	5	July 30	7	Aug. 11	12	32	69.81
Do.	...do.	4	July 17	3	July 19	2	July 25	6	Aug. 14	20	35	69.86
July 11	July 15	4	July 19	4	July 24	5	July 30	6	Aug. 12	13	32	69.58
Do.	...do.	4	...do.	4	...do.	5	...do.	6	...do.	13	32	69.58
Do.	July 16	5	...do.	3	July 25	6	Aug. 2	8	Aug. 13	11	33	69.69
Do.	July 15	4	...do.	4	...do.	6	Aug. 1	7	Aug. 12	11	32	69.58
Do.	...do.	4	...do.	4	...do.	6	Aug. 3	9	Aug. 13	10	33	69.69
Do.	July 14	3	July 18	4	July 23	5	July 30	7	Aug. 10	11	30	69.62
July 12	July 17	5	July 20	3	July 26	6	Aug. 4	9	Aug. 13	9	32	69.75
Do.	July 16	4	July 21	5	...do.	5	July 30	4	Aug. 15	16	34	69.32
Do.	July 17	5	...do.	4	July 30	9	Aug. 7	8	Aug. 14	7	33	69.42
July 13	July 19	6	July 23	4	July 29	6	...do.	9	Aug. 15	8	33	67.14
Do.	July 17	4	July 21	4	July 26	5	Aug. 2	7	Aug. 12	10	30	69.08
Do.	July 19	6	July 23	4	July 29	6	Aug. 7	9	Aug. 15	8	33	69.10
July 14	...do.	5	July 25	6	July 30	5	Aug. 9	10	Aug. 17	8	34	68.75
Do.	July 21	7	July 27	6	Aug. 4	8	Aug. 10	6	Aug. 19	9	36	68.63
Do.	July 19	5	July 25	6	Aug. 1	7	...do.	9	...do.	10	37	66.77
July 15	July 22	7	...do.	3	Aug. 5	11	Aug. 11	6	Aug. 21	10	37	68.36
Do.	July 21	6	...do.	4	Aug. 2	8	Aug. 10	8	Aug. 19	9	35	68.34
Do.	July 20	5	July 26	6	...do.	7	...do.	8	...do.	9	35	68.34
July 18	July 25	7	Aug. 2	8	Aug. 8	6	Aug. 14	6	Aug. 22	8	35	67.67
Do.	...do.	7	July 29	4	Aug. 6	8	Aug. 11	5	Aug. 20	9	33	67.79
Do.	Aug. 2	15	Aug. 7	5	Aug. 9	2	Aug. 15	6	Aug. 24	9	37	67.71
Do.	July 25	7	July 30	5	Aug. 8	9	Aug. 13	5	Aug. 22	9	35	67.84
July 19	July 29	10	Aug. 6	8	Aug. 11	5	Aug. 15	4	Aug. 25	10	37	67.92
Do.	July 24	5	July 27	3	Aug. 3	7	Aug. 9	6	Aug. 15	6	27	68.77
Do.	July 27	8	Aug. 3	7	Aug. 9	6	Aug. 15	6	Aug. 23	8	35	67.84
Do.	July 26	7	...do.	8	...do.	6	...do.	6	Aug. 24	9	36	67.71
Do.	July 25	6	...do.	9	...do.	6	Aug. 14	5	Aug. 23	9	35	67.84
Do.	July 28	9	Aug. 6	8	Aug. 12	6	Aug. 15	3	Aug. 25	10	36	69.81
July 20	July 27	7	July 29	2	Aug. 3	5	Aug. 9	6	Aug. 23	14	34	67.79
Do.	July 26	6	Aug. 3	8	Aug. 9	6	Aug. 14	5	Aug. 24	10	35	67.66
July 29	Aug. 8	10	Aug. 11	3	Aug. 15	4	Aug. 21	6	Aug. 31	10	33	67.53
Do.	Aug. 7	9	...do.	4	Aug. 17	6	Aug. 22	5	Sept. 1	10	34	67.73
Do.	Aug. 5	7	Aug. 10	5	Aug. 14	4	Aug. 21	7	Aug. 29	8	31	69.03
Do.	Aug. 7	9	Aug. 11	4	Aug. 15	4	...do.	6	Aug. 30	9	32	67.84
Do.	Aug. 8	10	Aug. 12	4	Aug. 16	4	Aug. 22	6	Sept. 1	10	34	67.73
Do.	Aug. 6	8	Aug. 11	5	...do.	5	...do.	6	...do.	10	34	67.73
July 30	Aug. 11	12	Aug. 14	3	Aug. 20	6	Aug. 25	5	Sept. 3	9	35	68.16
Do.	Aug. 7	8	Aug. 11	4	Aug. 15	4	Aug. 21	6	Aug. 30	9	31	67.68
Do.	Aug. 9	10	Aug. 14	5	Aug. 19	5	Aug. 25	6	Sept. 2	8	34	67.95
Do.	...do.	10	Aug. 12	3	Aug. 17	5	Aug. 22	5	Sept. 1	10	33	67.68
Aug. 5	Aug. 11	6	Aug. 15	4	Aug. 20	5	Aug. 25	5	Sept. 5	11	31	69.95
Do.	...do.	6	...do.	4	...do.	5	...do.	5	Sept. 3	9	29	68.55
Aug. 13	Aug. 19	6	Aug. 23	4	Aug. 27	4	Sept. 2	6	Sept. 8	6	26	71.52
Do.	Aug. 18	5	...do.	5	...do.	4	Aug. 29	2	Sept. 9	11	27	71.41
Do.	Aug. 21	8	...do.	2	Aug. 29	6	Sept. 3	5	Sept. 10	7	28	71.55
Do.	Aug. 18	5	Aug. 22	4	Aug. 26	4	Sept. 2	7	Sept. 8	6	26	71.52
Aug. 14	Aug. 20	6	Aug. 25	5	Aug. 31	6	Sept. 4	4	Sept. 11	7	28	71.75
Do.	Aug. 19	5	Aug. 24	5	Aug. 28	4	Sept. 3	6	Sept. 9	6	26	71.33
Do.	Aug. 20	6	...do.	4	Aug. 29	5	Sept. 5	7	Sept. 10	6	27	71.48
Do.	...do.	6	...do.	4	Aug. 28	4	Sept. 4	7	Sept. 11	7	28	71.75
Do.	...do.	6	...do.	4	...do.	4	Sept. 3	6	Sept. 9	5	26	71.33
Do.	Aug. 19	5	Aug. 23	4	Aug. 27	4	Sept. 2	6	Sept. 8	6	25	71.44
Do.	Aug. 20	6	Aug. 24	4	Aug. 29	5	Sept. 3	5	Sept. 9	6	26	71.33
Do.	Aug. 19	5	Aug. 23	4	Aug. 27	4	Sept. 2	6	...do.	7	26	71.33
Do.	Aug. 20	6	Aug. 25	5	Aug. 29	4	Sept. 3	5	...do.	6	26	71.33
Do.	...do.	6	Aug. 26	6	Sept. 2	7	Sept. 6	4	Sept. 14	8	31	71.24
Do.	Aug. 19	5	Aug. 23	4	Aug. 27	4	Sept. 3	7	Sept. 9	6	26	71.33
Do.	Aug. 24	10	Aug. 29	5	Sept. 2	4	...do.	1	Sept. 10	7	27	71.48

TABLE XI.—*Length of each of the five nymphal stages of the grape leafhopper for 114 nymphs recorded from June 22 to October 13, 1912*—Continued.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average daily temperature for entire nymphal period.
1912:	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	1912.	*Dys.*	*Dys.*	°*F.*
Do	Aug. 20	6	Aug. 25	5	Sept. 1	7	Sept. 4	3	Sept. 10	6	27	71.48
Do	do	6	Aug. 24	4	Aug. 29	5	Sept. 3	5	Sept. 9	6	26	71.33
Do	do	6	Aug. 25	5	Sept. 1	7	do	2	Sept. 10	7	27	71.48
Do	do	6	Aug. 24	4	Aug. 27	3	Sept. 2	6	Sept. 9	7	26	71.33
Aug. 15	Aug. 23	8	Aug. 26	3	Aug. 31	5	Sept. 4	4	Sept. 10	6	26	71.57
Do	Aug. 21	6	do	5	do	5	do	4	do	6	26	71.57
Do	do	6	do	5	Aug. 30	4	do	5	do	6	26	71.57
Do	do	6	do	5	Aug. 31	5	do	4	do	6	26	71.57
Do	do	6	Aug. 25	4	Aug. 30	5	do	5	Sept. 9	5	25	71.42
Do	do	6	do	4	do	5	Sept. 2	3	Sept. 10	8	26	71.57
Aug. 16	do	5	do	4	do	5	Sept. 3	4	do	7	25	71.80
Do	do	5	do	4	Aug. 31	6	Sept. 4	4	do	6	25	71.80
Aug. 17	do	4	Aug. 26	5	Sept. 1	6	do	3	Sept. 11	7	25	72.40
Do	Aug. 22	5	do	4	Sept. 2	7	Sept. 5	3	do	6	25	72.40
Do	do	5	do	4	Sept. 1	6	do	4	do	6	25	72.40
Do	do	5	Aug. 27	5	do	5	do	4	do	6	25	72.40
Aug. 20	Aug. 25	5	Aug. 30	5	Sept. 3	4	Sept. 6	3	Sept. 13	7	24	76.58
Do	Aug. 24	4	Aug. 27	3	Sept. 2	6	Sept. 5	3	Sept. 11	6	22	73.20
Aug. 21	Aug. 25	4	Aug. 30	5	Sept. 3	4	Sept. 6	3	Sept. 12	6	22	72.95
Do	do	4	Aug. 29	4	Sept. 2	4	do	4	Sept. 13	7	23	72.65
Do	Aug. 26	5	Sept. 1	6	Sept. 4	3	Sept. 7	3	Sept. 14	7	24	72.66
Do	Aug. 25	4	Aug. 29	4	Sept. 2	4	Sept. 6	4	Sept. 12	6	22	73.18
Do	Aug. 26	5	Sept. 1	6	Sept. 4	3	Sept. 7	3	Sept. 14	7	24	72.66
Do	Aug. 25	4	Aug. 31	6	Sept. 3	3	Sept. 6	3	Sept. 13	7	23	72.65
Do	Aug. 26	5	do	5	do	3	Sept. 7	4	Sept. 15	8	25	72.74
Aug. 22	Aug. 27	5	Sept. 2	6	Sept. 5	3	Sept. 8	3	do	7	24	72.83
Do	Aug. 26	4	Aug. 31	5	Sept. 3	3	Sept. 7	4	Sept. 14	7	23	72.78
Do	do	4	Sept. 1	6	Sept. 4	3	do	3	Sept. 15	8	24	72.83
Do	do	4	do	5	do	3	do	3	Sept. 14	7	25	72.78
Aug. 30	Sept. 3	4	Sept. 7	4	Sept. 9	2	Sept. 13	4	Sept. 22	9	23	72.50
Sept. 4	Sept. 7	3	Sept. 14	7	Sept. 15	1	Sept. 22	7	Oct. 6	14	32	65.01
Do	do	3	Sept. 12	5	do	3	Sept. 23	8	Oct. 8	15	34	64.41
Do	do	3	Sept. 11	4	Sept. 14	3	Sept. 20	6	Oct. 6	16	32	65.01
Sept. 6	Sept. 10	4	Sept. 14	4	Sept. 19	5	Sept. 25	6	Oct. 12	17	36	63.64
Do	do	4	do	4	Sept. 18	4	do	7	do	17	36	63.64
Do	do	4	do	4	Sept. 19	5	do	6	do	17	36	63.64
Do	do	4	do	4	do	5	Sept. 24	5	Oct. 10	16	34	63.53
Do	do	4	Sept. 13	3	Sept. 18	5	Sept. 25	7	Oct. 13	18	37	63.32
Do	do	4	Sept. 14	4	do	4	do	7	do	18	37	63.32

TABLE XII.—*Maximum, minimum, and average temperatures taken at the field laboratory, North East, Pa., from June 1 to October 31, inclusive.*

Day of the month.	June.			July.			August.			September.			October.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
1	70	50	60.0	72	53	62.5	66	52	59.0	84	65	74.5	57	49	53.0
2	78	64	71.0	75	58	66.5	69	53	61.0	86	68	77.0	64	45	54.5
3	77	59	68.0	82	68	75.0	63	64	63.5	81	69	75.0	70	54	62.0
4	76	60	67.5	83	68	75.5	65	49	57.0	79	69	74.0	67	56	61.5
5	69	44	56.5	84	68	76.0	65	54	59.5	87	68	77.5	70	51	60.5
6	67	54	60.5	84	70	77.0	70	50	60.0	84	69	76.5	77	54	65.5
7	68	46	57.0	92	72	82.0	71	55	63.0	86	70	78.0	69	49	59.0
8	59	38	48.5	87	71	79.0	78	54	66.0	77	56	66.5	58	43	50.5
9	66	45	55.5	85	73	79.0	78	66	72.0	77	62	68.5	71	51	61.0
10	65	58	61.5	80	72	76.0	78	67	72.5	83	68	75.5	67	56	61.5
11	70	55	62.5	87	69	78.0	76	63	69.5	89	69	79.0	73	50	66.0
12	78	60	69.0	85	66	75.5	76	61	68.5	74	58	66.0	74	54	64.0
13	68	49	58.5	82	65	73.5	80	67	73.5	76	54	60.5	59	46	52.5
14	61	48	54.5	87	69	78.0	79	59	69.0	78	68	73.0	59	45	52.0
15	78	60	69.0	83	73	78.0	69	63	66.0	80	69	74.5	55	44	49.5
16	72	57	64.5	92	61	76.5	72	56	64.0	82	60	71.0	55	39	47.0
17	77	57	67.0	74	63	68.5	67	53	59.5	62	49	55.5	63	46	54.5
18	69	50	59.5	77	63	70.0	69	64	66.5	69	59	64.0	71	56	63.5
19	65	48	56.5	82	57	69.5	78	67	72.5	73	60	66.5	63	52	57.5
20	64	57	60.5	65	52	58.5	71	63	67.0	69	54	61.5	54	45	49.5
21	71	57	64.0	75	63	69.0	75	65	70.0	68	57	62.5	71	48	59.5
22	67	59	63.0	77	63	70.0	76	60	68.0	79	63	72.0	65	56	60.5
23	69	49	49.0	73	54	63.5	75	65	70.0	77	56	66.5	56	43	49.5
24	70	50	60.0	72	60	66.0	69	57	63.0	62	55	58.5	44	41	42.5
25	74	65	69.5	70	68	69.0	80	71	75.5	69	61	65.0	48	44	46.0
26	80	61	70.5	75	61	68.0	82	66	74.0	78	61	68.5	54	44	49.0
27	78	58	68.0	75	52	63.5	82	58	70.0	64	47	55.5	56	41	48.5
28	82	67	74.5	70	57	63.5	62	52	57.0	56	43	48.5	60	47	53.5
29	77	64	70.5	75	64	69.5	59	54	56.5	63	47	55.0	70	55	62.5
30	83	59	71.0	73	57	65.0	67	48	57.5	51	36	43.5	63	64	54.5
31	.....	.....	.....	72	52	62.0	63	59	61.0	.....	.....	.....	54	44	49.0

SUMMARY OF SEASONAL HISTORY OF THE GRAPE LEAFHOPPER.

The grape leafhopper (see fig. 1, p. 1) hibernates as an adult among accumulations of leaves and trash in vineyards, but mostly in adjoining woodlands, hedgerows, and pastures. It becomes active during the first warm days of spring and commences feeding on the new growth of almost any of the plants with which it comes in contact. With the unfolding of the grape leaves there is a general migration of the insect to the vineyards. In normal seasons this takes place about the middle of May in the vineyards of the Lake Erie Valley. After feeding for a few days the leafhoppers mate, and oviposition commences early in June. The eggs are deposited singly and are tucked under the epidermis beneath the pubescence of the underside of the grape leaf. The average length of the egg stage is from 11 to 15 days. The nymphs commence to appear on the underside of the leaves about the 20th of June, and by the end of the first week in July a large percentage of the first brood has hatched and is present in one of the several nymphal stages,

of which there are five. (See Pl. I.) The average length of the nymphal period is about 28 days, but with many it varies from 20 to 35 days. At the last nymphal molt the adults have fully developed wings. A few newly transformed adults may be found in vineyards from about July 7 to July 12.

In normal seasons, however, the majority of the first-brood adults appear after the middle of July. Observations of the development of the insect indicate that if the nymphal period is lengthened by low temperatures during the month of July, the number of adults of the new brood that will mate and deposit eggs for a second brood is quite small; whereas, if high temperatures prevail during the early part of July, a large number of the nymphs are likely to develop rapidly and make their transformation about the middle of July. These early maturing adults mate and deposit eggs, and the resulting second brood of nymphs is quite large.

Mating of the first-brood adults appears to be common for only a few days. In 1912 few mating pairs were seen except during the period from July 23 to July 27.

Early in August the color markings on the elytra of the adults change from light yellow to a pale salmon color, which becomes more intense as the season advances. After the appearance of this change in coloration of the elytral markings little oviposition occurs.

By the early part of September most of the nymphs of both the first and second broods have transformed to adults, although a small number of nymphs may be found on the foliage until quite late in the fall. Toward the middle and latter part of September the adults commence to migrate from the vineyards and during warm, calm afternoons may be seen in swarms drifting through the air in an apparently aimless manner. They usually come to rest in adjoining woodlands or rough pasture lands. Here they remain more or less active during the warmer parts of the days of October and the late fall, seeking the shelter of leaves and trash at night and during the cooler days, and becoming less active as the cold weather of winter approaches.

REARING CAGES USED.

Since the adult grape leafhoppers are very agile creatures it was impossible to study their habits and life history in detail on the large fruiting vines in the open vineyard. Yet in order that the adults might oviposit and the eggs develop normally, it was necessary that the insects studied should be confined on healthy growing grape foliage. For this purpose a large number of young grape-vines, including several varieties, were planted in the garden of the laboratory early in the spring of 1912. The vines were planted in rows about 3 feet apart. Those vines used for securing egg records,

longevity of overwintering adults, number of eggs deposited per female, length of nymphal stages, etc., were covered with a cage early in the season so as to prevent the foliage from becoming infested by other adults.

Since it was impossible to secure enough Riley cages, or to have cages made that were sufficiently tight to prevent the escape of the adults, recourse was taken to the use of a number of second-hand arc-light globes, which were secured from the local lighting plant. These were about 15 inches high, with a small opening about 4 inches in diameter and a large opening about 8 inches in diameter. The globe was placed over the vine with the lower opening resting on the ground, and the larger opening was covered with a piece of muslin fastened to a stout wire ring. This cover was drawn tightly over the large opening by means of four cords fastened to the wire ring and connected to four pegs driven into the ground and tightened in the same manner as are the cords of a tent. In this way it was possible to draw the muslin perfectly tight all around the edge of the upper opening of the globe. The insects were examined during the cooler part of the day when they were least active. It was found that when the lower opening was set into the ground, the temperature inside of the cage was several degrees higher than that on the outside, owing to a lack of circulation of air inside the cage. This was overcome by taking a strip of fine wire screen about 4 inches wide and forming it into a collar a little larger than the smaller opening of the globe. This collar was then slipped over the young grapevine and pressed firmly into the soil. The globe was then placed over the vine and the small opening fitted into the wire screen collar, thus securing an air current into the bottom of the cage up through the muslin cover or vice versa. The muslin cover was then made large enough to shade the greater part of the globe. These modifications resulted in securing a cage that was light and tight, and that had a temperature about the same as that on the outside.

The cage that has just been described (see Pl. II, fig. 1) is spoken of as an "arc-light globe cage" in connection with the rearing experiments mentioned under seasonal history.

A smaller cage, employed for rearing single nymphs for the purpose of recording the length of the stages of individuals, is fully described on page 26 under another caption dealing with experiments to determine the length of the nymphal stages.

PARASITES AND PREDACEOUS ENEMIES.

Apparently the grape leafhopper suffers little from the attack of parasitic enemies. No records of parasites have been found in the literature dealing with this pest. During the investigations on grape insect pests conducted at North East, Pa., from 1907 to 1912, only

one instance of parasitism was noted. In this instance, on July 31, 1907, Mr. P. R. Jones, of the Bureau of Entomology, observed the female of *Aphelopus* sp. in the act of thrusting her ovipositor into the body of a nymph. No attempt was made to determine if eggs were deposited in the body of this nymph, nor was any further evidence of parasitism of the nymphs or the adults of the grape leafhopper observed.[1]

On the other hand, the nymphs seem to be especially subject to the attack of many predaceous insects, mites, and spiders, while the adults become entangled in spider webs and are preyed upon by the occupants.

FIG. 13.—Adult grape leafhopper parasitized by a dryinid, and showing cocoon of parasite protruding from abdomen, at left. Greatly enlarged. (Original.)

The literature on the grape leafhopper contains the following records of attack by predaceous enemies on either the nymphs or the adults:

B. D. Walsh, in 1862, records *Hemerodromia superstitiosa* Say, one of the dance flies, as feeding on the "hoppers" in Illinois.

Townend Glover, in 1875, records *Hyaliodes vitripennis* Say, the glassy-winged soldier-bug, as feeding on the nymphs.

M. V. Slingerland, in 1902, records a mite, *Rhyncholophus parvulus* Banks, the larvæ of Chrysopa, and aphis lions as feeding on the nymphs.

J. H. Quayle, in 1908, records the destruction of the nymphs by the beetles and larvæ of ladybirds, aphis lions, and ants, but states that all of these predaceous enemies put together have little apparent influence in lessening the number of the pest.

During the investigation of this pest at North East, Pa., aphis lions, ants, mites, and spiders were frequently observed preying upon the nymphs, and in addition to them a very active orange-colored mite (*Anystis agilis* Banks) was often found feeding upon the nymphs and occasionally upon the adults, especially just after the latter had transformed and had not the full use of their wings. Both the nymph and the adult of a capsid of the genus Diaphnidia near *D. hamata* Van Duzee were frequently found with nymphs of *T. comes* impaled on their long probosces. Yet all of these predaceous enemies combined failed to have any appreciable influence in reducing the destructive numbers of the leafhopper.

[1] While Mr. J. F. Strauss, of this bureau, was making drawings of adults of *T. comes* for this paper he found an adult among some material in alcohol with the pupa of a dryinid (see fig. 13) attached to the body. These specimens were collected by the writer in vineyards near Euclid, Ohio, Aug. 9, 1911.

NATURAL CHECKS.

It would seem, however, that there are some as yet unknown natural checks which greatly reduce the numbers of this insect and occasionally almost entirely eliminate it over areas where only a short time previously it had been a serious pest.

In 1865 Trimble observed that once when the thermometer reached 100° F. thousands of the "hoppers" were killed.

There was a great diminution in numbers of the adults in the infested area of the Chautauqua County vineyards early in the season of 1903.

A condition similar to this was observed by Mr. E. W. Scott, of the Bureau of Entomology, during the season of 1912, when adults of *Typhlocyba tricincta* were so very abundant in the vineyards near Benton Harbor, Mich., that the vineyardists became greatly alarmed, many of them making preparations to spray the nymphs when they should appear. Yet this proved unnecessary, for when the time arrived for the nymphs to appear upon the foliage in large numbers most of the adults had disappeared and very few nymphs of the new brood had hatched. As yet nobody appears to be able to account for these sudden disappearances of the pest or to determine whether they are due to climatic or other causes.

In September, 1890, Thaxter observed that in Connecticut grape leafhoppers in large numbers were injuring a vineyard. He found that they were attacked by a fungous disease (*Empusa* sp.) which apparently destroyed all of them. This is the only case on record in which this insect was attacked by a fungous disease. Nothing of this nature has been observed in the vineyards of the Lake Erie Valley during the present investigation, and for the past four or five seasons the pest has steadily increased. Probably the time may not be far distant when large numbers of them will suddenly disappear, as happened at Westfield, N. Y., in the season of 1903. However, it is by no means safe for the vineyardist to count on these natural checks, for while one is waiting for relief from such a source the pest may work incalculable damage to his vineyard.

REMEDIES.

During the period that this insect has attracted the attention of economic entomologists much experimental work has been undertaken to determine the most effective means for its control. Early in the control work undertaken against this pest, tobacco, in some form or other, was employed as a killing agent. In 1828 Fessenden (see Bibliography) recommended the smoking of infested vines by burning tobacco stalks beneath them.

In 1843 J. F. Allen (see Bibliography) advised syringing or spraying infested vines and also smoking them by burning tobacco stalks. Since this date the use of tobacco in both of the forms mentioned has occupied a prominent place among substances recommended for the control of the grape leafhopper. The former method, that of fumigation, however, was impracticable for the open vineyard. In fact, it is quite probable that the process of fumigation with tobacco was originally intended for use against the insect when found infesting grapevines growing in hothouses which could be closed during the period of treatment. On the other hand, the use of a liquid tobacco decoction has withstood the test of numerous experiments in comparison with a large number of liquid spray materials and at the present time is the insecticide most generally recommended in making spray applications against the nymphs.

In the following paragraphs is presented a list of substances and mechanical methods either experimented with or recommended by various entomologists (see Bibliography) since this insect has been a pest of economic importance:

Liquid sprays.—Syringing with tobacco water or soapsuds (W. Saunders, 1870). Spraying with carbolic acid (W. L. Devereaux, Rural New Yorker, 1883). Spraying with kerosene and water, or sheep dip (O. Lugger, 1896). Spraying the adults with kerosene and water and the nymphs with whale-oil soap (M. V. Slingerland, 1904).

Dust sprays.—Dusting with lime and sulphur (C. J. S. Bethune, 1868). Dusting with hellebore (W. Saunders, 1870).

Other mechanical methods.—The use of sticky shields to trap the adults; torches to attract the adults (C. V. Riley, 1873). Destruction of leaves to destroy adults in hibernation (A. J. Cook, 1875). Sticky shields and cloth wet with kerosene to trap adults (J. A. Lintner, 1887). Sheets of cardboard smeared with tar to trap adults (F. M. Webster, 1893). Burning of leaves and rubbish in and surrounding vineyards to destroy adults in hibernation (O. Lugger, 1896). Sticky fans to catch adults as they fly from vines; collecting nets to catch adults (C. W. Woodworth, 1897). Box or cage having inside smeared with a sticky substance; the cage is placed over the infested vine and the "hoppers" are caught on the sticky sides and bottom of the cage (H. J. Quayle, 1908). Sticky shields held on both sides of the trellis (M. V. Slingerland, 1904).

Many of the methods of control mentioned in the foregoing paragraphs have been recommended by various other authors treating this subject. The foregoing simply indicate the date of their first mention in literature.

In his experimental work in vineyards in Chautauqua County, N. Y., Slingerland carried on quite extensive experiments with sticky shields for catching the adults before the commencement of egg deposition, the most practical shield for trellised vineyards being constructed and used as follows:

Make a light wooden frame about seven or eight feet long and four feet wide, having the bottom crosspiece about a foot from the ground and fasten to this stiff wires extending down nearly to the ground and bent inward something like hay-rake teeth. Tack over this a strip of table oilcloth $1\frac{1}{4}$ yards wide and let it extend down over the

curved wire teeth, so that when the shield is held beside a vine, the oilcloth will come under the vine to catch the "hoppers" that try to drop to the ground. Cover the oilcloth with the "stick-em" and all is ready to operate. Two men, each carrying one of these light sticky shields on opposite sides of a trellis of vines, can reach over the shields, jar the vines to disturb the "hoppers" and thus go over an acre of vineyard in a little more than an hour.

In California, where the vines are not trained to a trellis, Mr. Quayle found that a screen cage having the inside smeared with crude oil, with one side open and a V-shaped opening cut in the bottom to admit the stem of the vine, could be used quite effectively in the vineyards to catch the adults before egg deposition commenced. In the course of his field experiments in California Mr. Quayle conducted experiments with suction apparatus for collecting the adults from the vines. He also attempted to destroy them with torches; by the application of dry powders, including lime, hellebore, and dry sulphur; and also by the fumigation of infested vines, both with cyanid and sulphur gas. None of these latter methods gave results of a practical nature, and the only mechanical method of control against the adults recommended by him is that of the screen cage previously mentioned.

Destruction of leaves and trash.—Many authors have urged the destruction of leaves and trash in and adjoining infested vineyards, while the insects are in hibernation, as a means of lessening their numbers. However, since the adults rise in the air and either fly or are carried considerable distances by the winds during the migrations which take place during the spring and fall, there are usually large areas of wood lots and pasture lands at considerable distances from vineyards where swarms of the adults may be found during the winter. Since in many cases these areas of rough land are not controlled by the owners of the vineyards there is slight possibility that this cleaning-up process will be undertaken on a large enough scale to be of any great value in lessening the numbers of overwintering adults. Furthermore, at the present time there is a strong tendency toward the growing of some form of cover crop, such as clover, vetch, turnips, rye, oats, etc., in vineyards as a means of furnishing soil protection and fertility; and this is very necessary and desirable in most of the vineyards of the Lake Erie Valley. This would have to be abandoned if the clean-culture method were followed. Observations along this line covering several seasons indicate that where cover crops are growing in badly infested vineyards the number of adult grape leafhoppers found among the shelter thus afforded is generally very small compared with the number that have migrated to adjacent wood lots and rough pasture lands. In fact, it would appear that there is a tendency for the larger percentage of adults to migrate from the vineyards in the fall, and this migration appears to be their chief mode of dispersal as much as a means for securing suit-

able hibernating quarters. Hence too much should not be expected of this destruction of leaves and trash on a limited scale, since in the following spring the adults are likely to swarm back into the vineyards from areas not included in the cleaning-up process.

SPRAY TREATMENT.

During recent years a great deal of attention has been given to combating this pest by means of liquid sprays. Owing to the agility of the winged adults, and also to the fact that their sloping wing covers protect their soft bodies from the killing action of spray liquids not sufficiently caustic to injure the foliage of the grapevines, it is a very difficult task to destroy many of them with liquid spray applications. This was demonstrated by Prof. Slingerland in his field experimental work in the vineyards of Chautauqua County, N. Y., during the outbreak of 1901–2. Since it frequently happens that during seasons of heavy infestation the hibernating adults appear on the new foliage in injurious numbers and cause considerable alarm among the vineyardists, he attempted to combat them by means of a kerosene and water spray. He found, however, that the margin between the percentage of oil necessary to kill the adults and the percentage that would seriously injure the grape foliage was so small that more injury to the vines was likely to occur than would offset the benefit derived from the number of flying adults that were killed by the process.

Much greater success, however, was secured by him in spray applications made against the nymphs by the use of whale-oil soap at a strength of 1 pound of the soap to 10 gallons of water. With this spray liquid he was able, by one thorough application when the majority of the nymphs were present on the foliage, to reduce their numbers to such an extent that those remaining caused no serious injury to the vines for the remainder of the season.

In experiments with liquid sprays consisting of 1 pound of whale-oil soap to 15 gallons of water Mr. Quayle was able to destroy a very large percentage of the nymphs infesting grapevines in California. He was also able to obtain good results by the use of a spray consisting of 1 pound of resin to 15 gallons of water, using enough lye or potash completely to dissolve the resin. This required 1 pound of lye to about 8 pounds of resin.

The chief objections to the use of whale-oil soap are the very offensive odor connected with its application and the fact that since the vines have to be thoroughly drenched with the spray in order to strike the underside of all of the leaves, the clusters of grapes are also necessarily drenched. This soapy liquid has a tendency to form in a drop on the lower part of each berry, and after the moisture has evaporated a white stain remains which makes an undesirable discolora-

tion on the purple surface of the ripened grapes, rendering them unattractive for table use.

During the last few years commercial brands of tobacco extracts have come much into use as liquid spray substances for the control of soft-bodied sucking insects. Hence once more, after a period of over 80 years since it was first recommended, tobacco appears to be the most promising insecticide for the control of this pest.

During the seasons of 1910 and 1911 the grape leafhopper was present in very injurious numbers in many vineyards in the Lake Erie Valley. Vineyard experiments were undertaken by the Bureau of Entomology in the vicinity of North East, Pa., using the tobacco extracts as liquid sprays against the nymphs. The results of these experiments were very gratifying, since with one thorough application of the tobacco extract the numbers of these insects in the treated vineyards were so greatly reduced and the injury was so slight that the foliage retained its dark green color throughout the season, the cane growth was strong and well matured, the berries were large, the fruit sweet, and the size of the crop considerably increased; whereas, on the untreated portion of the vineyards the foliage turned brown and dropped prematurely, the cane growth was stunted, the berries were undersized and lacking in sugar content, and the tonnage per acre was much less than on the sprayed portions of the vineyards.

Detailed reports of these vineyard experiments against this pest are given in Part I of Bulletin No. 97 and Part I of Bulletin No. 116 of this bureau.

SPRAY MATERIAL.

The forms of tobacco extract used in these experiments in 1910 and 1911 were the blackleaf tobacco extract containing 2.70 per cent nicotine sulphate and the blackleaf tobacco extract containing 40 per cent of nicotine sulphate. The blackleaf tobacco extract containing 2.70 per cent of nicotine was effective in killing all of the nymphs which were thoroughly wetted by the spray, when applied at a dilution of 1 part of tobacco extract to 150 parts of water or Bordeaux mixture. The blackleaf tobacco extract containing 40 per cent nicotine sulphate was found to be effective at a dilution of 1 part of tobacco extract to 1,500 parts of water or Bordeaux mixture. Both of these forms of tobacco extract appear to be equally effective in destroying the nymphs at the dilutions mentioned. The one containing the smaller percentage of nicotine (2.70 per cent), however, necessarily contains more sticky inert matter. When this is applied as a spray to the vines late in the season, i. e., toward the middle of August, and when little rainfall occurs before the harvesting season, some of this sticky substance may adhere to the ripe grapes, giving the skins a slight flavor of tobacco.

It was noted that this condition obtained during the dry fall of 1910. The "blackleaf 40" tobacco extract does not appear to carry so much of this sticky substance, and owing to the greater dilution that is possible in its use the dilute spray liquid is almost clear; hence there is not the likelihood that it will leave the undesirable stain on the ripened fruit. It should be stated, however, that neither of these extracts is likely to leave the unpleasant stain or odor on the fruit if applied in the early part or middle of July, which is usually the period at which the maximum benefit is to be derived from them in the destruction of the nymphs.

SPRAYING APPARATUS.

Various types of spraying machinery are used by the vineyardists of the Lake Erie Valley. It was on account of the depredations of the grape rootworm, requiring a spray application to the upper surface of the foliage, that the use of spraying machinery in vineyards became general. The sprayer in general use for this work is of the tractor type (Pl. III, fig. 1), the power being generated either by a chain or an eccentric gearing connecting the wheel and the pump. Thus in order to maintain a uniform high pressure with this type of machine it is necessary to keep it in motion. Although most of these machines are supplied with a large air chamber so that the pressure is held quite steady and does not vary with every stroke of the plunger, yet as soon as the wheels of the machine stop turning the pressure drops quite rapidly.

Other types of sprayers in use for vineyard work are compressed-air power outfits, gasoline-engine power outfits, and steam power outfits. With all of these latter types the pressure is independent of the rate of movement of the machine through the vineyard rows.

In making spray applications against the nymphs of the grape leafhopper it is necessary to apply large quantities of spray liquid to the underside of the infested grape leaves. Where the foliage is quite dense the amount of spray required for thorough work may amount to from 200 to 300 gallons per acre, whereas in making applications to the upper surface of the foliage against the beetles of the grape rootworm thorough work can be done on quite dense foliage with about 100 to 125 gallons of liquid per acre, and this may be accomplished while the team is being driven slowly.

During the seasons of 1911 and 1912 all of the types of spray machinery previously mentioned were observed in use in spraying against the grape leafhopper, and in the hands of careful operators effective work was accomplished with all of them.

It should be stated that in all cases observed, with the exception of the steam-engine power outfit, all of the spray applications were made by the trailer method. That is, the operator directed the spray

to the underside of the grape leaves by holding a short rod, one end connected to the spray hose and the free end carrying a large nozzle of the cyclone type directed upward at right angles to the rod. (See Pl. III, fig. 1.) Effective results in killing the nymphs by this method appeared to depend more upon the person manipulating this rod than upon the type of sprayer used or the number of pounds of pressure applied, providing the pressure was not allowed to drop below 75 pounds. Of course with the higher pressure larger areas can be covered in a given time than with the low pressure. Yet the most effective work done in the control of this pest coming under observation of the writer was accomplished with a tractor machine, with a pressure fluctuating between 70 and 125 pounds, in the hands of a very thorough vineyardist. This feature is emphasized here because the small vineyardist, being under the impression that an expensive high-pressure spray outfit is necessary, is frequently deterred in attempting to control this pest, whereas the most important thing is care in the direction of the spray so that the greatest number of nymphs will be drenched, and this can be done with the same tractor machine that is used for applications against the grape rootworm. On the other hand, it is doubtless much more economical for the vineyardist with large areas to cover to have larger high-pressure outfits, since with them two or even more leads of hose may be used (Pl. III, fig. 2), making it possible to cover large areas in a very short time. This is highly desirable, since there are only about 8 to 12 days during which the maximum number of nymphs is present upon the foliage.

In order to lessen the time required to make the application and to reduce the cost, many attempts have been made to apply the spray to the underside of the grape foliage by means of a fixed nozzle arrangement instead of making the application by the trailer method described above. The chief difficulty arising in the use of a fixed-nozzle arrangement is that such a device applies no more liquid to a vine carrying a large amount of dense foliage than to one carrying a moderate amount of more widely spaced foliage; hence it frequently happens that much more spray than is necessary is applied to the vine carrying light foliage and not enough is applied to the one carrying dense foliage.

The types of fixed-nozzle arrangement are being tried out in the vineyards of the Lake Erie Valley. One of these was for a tractor or a gasoline-engine power sprayer, and was devised and used by Mr. F. Z. Hartzell.[1] The other arrangement was used for a steam-engine power sprayer. (Pl. II, fig. 2.) Both of these arrangements are reported to have given fairly satisfactory results in killing nymphs where the foliage was not very dense. In most cases, however, suc-

[1] Bul. 344, N. Y. (Geneva) Exp. Sta., Pls. I-IV.

FIG. 1.—ROD AND SINGLE CYCLONE NOZZLE USED TO APPLY SPRAY TO UNDERSIDE OF GRAPE FOLIAGE. POWER SUPPLIED BY TRACTOR SPRAYER. VINEYARD OF MR. H. H. HARPER, NORTH EAST, PA. (ORIGINAL.)

FIG. 2.—GASOLINE-ENGINE SPRAYER SUPPLYING POWER FOR TWO "TRAILER" LEADS OF HOSE IN SPRAYING AGAINST THE GRAPE LEAFHOPPER. VINEYARD OF MR. J. E. BEATTY, NORTH EAST, PA. (AUTHOR'S ILLUSTRATION.)

cess with any type of spray apparatus in present use in work against this pest appears to depend more on the care and ingenuity of the individual operator than upon the great superiority of any given type of machine over another.

RECOMMENDATIONS.

Efforts to control the depredations of the grape leafhopper by the destruction of the winged adults, by burning over or cleaning up their hibernating places adjacent to vineyards, by trapping them on sticky shields, or by endeavoring to treat them with contact sprays when they appear on the new growth of the grapevines in spring before oviposition takes place, have proven far from satisfactory. Although these methods may furnish a certain measure of relief over very limited areas, they are of very slight practical value as control measures when serious infestations occur in large vineyards.

Observations indicate that except in seasons of extremely heavy infestation, or over limited areas, the injury wrought by the overwintering adults in spring to the new growth is not likely to reduce greatly the entire seasonal growth of the infested grapevine provided a large percentage of their offspring in the form of nymphs can be destroyed before they reach the adult stage. In other words, it is the steady drain made on the infested grapevines from the time the overwintering adults attack them in spring, combined with the unchecked attack of the nymphs and adults of the new brood until late September, that results in serious injury by curtailing the size of the crop and the growth of the vine.

That the nymphs can be controlled by the spray method has been thoroughly demonstrated. Successful control of the nymphs by this method depends on thoroughly wetting all parts of the underside of the infested leaves with the spray liquid.

Tobacco extracts have given excellent results, used according to the following formulas:

I. Tobacco extract containing 2.70 per cent nicotine sulphate, diluted at the ratio of 1 part to 150 parts of water.

II. Tobacco extract containing 40 per cent nicotine sulphate, diluted at the ratio of 1 part to 1,500 parts of water.

The killing quality of the tobacco extract is apparently just as effective when added at the same dilution to the Bordeaux mixture and arsenate of lead spray liquids, which are used to control fungous diseases and chewing insect enemies of the grapevine, as when used with clear water. No injury results from combining these spray mixtures, namely, tobacco extract, Bordeaux mixture, and arsenate of lead. However, the tobacco extract should not be mixed with spray mixtures containing arsenicals in the form of Paris green or arsenite of lime, for serious injury to the foliage is likely to occur as a result of the combination.

The most effective time to make the tobacco spray application against the nymphs is just before those that hatched earliest in the season have reached the fourth molt. This can be determined by the length of the wing pads (Pl. I) which, in the fourth stage, extend about one-third the length of the abdomen. At this time a larger number of nymphs are likely to be present on the vines than at any other time during the season. In the vineyards of the Lake Erie Valley this condition occurs toward the end of the first week in July, and the most effective work with the tobacco-spray liquid may be done during the two weeks following this date. After this period, or toward the end of July, a large percentage of the nymphs of the first brood will have transformed to winged adults, and these latter can not be successfully treated with the diluted tobacco spray.

In vineyards where black-rot, mildew, the grape rootworm, and the grape-berry moth occur, it is suggested that arsenate of lead and Bordeaux mixture be used with the tobacco extract to take the place of the second spray application in the schedule of treatment recommended against these diseases and insect pests.

When it is deemed expedient to use sticky shields to capture the winged adults before oviposition takes place, the best sticky substance for this purpose, according to Slingerland, is a mixture of melted resin, 1 quart, in 1 pint of castor oil, smeared liberally over the face of the shield.

CONCLUSIONS.

Typhlocyba comes, the species of grape leafhopper discussed in this paper, is at the present time a very destructive enemy of the grapevine throughout the vineyards of the Lake Erie Valley. For several seasons it has caused great losses to the vineyardists of this region by reducing the yield and quality of the grape crop and by curtailing the growth and lowering the vigor of the vines. The vineyardist who desires to maintain his vines in full vigor and produce high-quality fruit can not afford to allow this pest to develop in destructive numbers in his vineyards, for if not controlled sooner or later it is almost sure to occasion serious loss. Field experiments prove conclusively that this pest can be controlled by spraying against the nymphs with a tobacco-extract solution.

The life-history studies recorded in the preceding pages show that there is only one full brood of nymphs a year in the region of the Great Lakes.

The spraying experiments recorded in Part I of Bulletin 97 and Part I of Bulletin 116 of the Bureau of Entomology indicate that a single thorough spray application, made when the greater percentage of the nymphs of this brood is present on the underside of the grape leaves, will so reduce their numbers that injury to the crop and the

vines for the remainder of the season by those that escape the spray action will be very slight.

In the vineyards of Ohio, west of Cleveland, and in the vineyards of Michigan another species of grape leafhopper, *Typhlocyba tricincta* (figs. 6 and 7, pp. 10, 11), is the predominant and destructive species. The life history and habits of this species, however, are so nearly identical with those of *Typhlocyba comes* that the remedial treatment recommended for the latter can also be used with success against the former, namely, the application of the tobacco-extract spray to the nymphs at the time they appear in maximum numbers upon the underside of the grape leaves, which for these States is during the last few days in June or very early in July.

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